Homogeneous nucleation and its role in CRYSTAL-FACE anvil cirrus—– Part II: Model results

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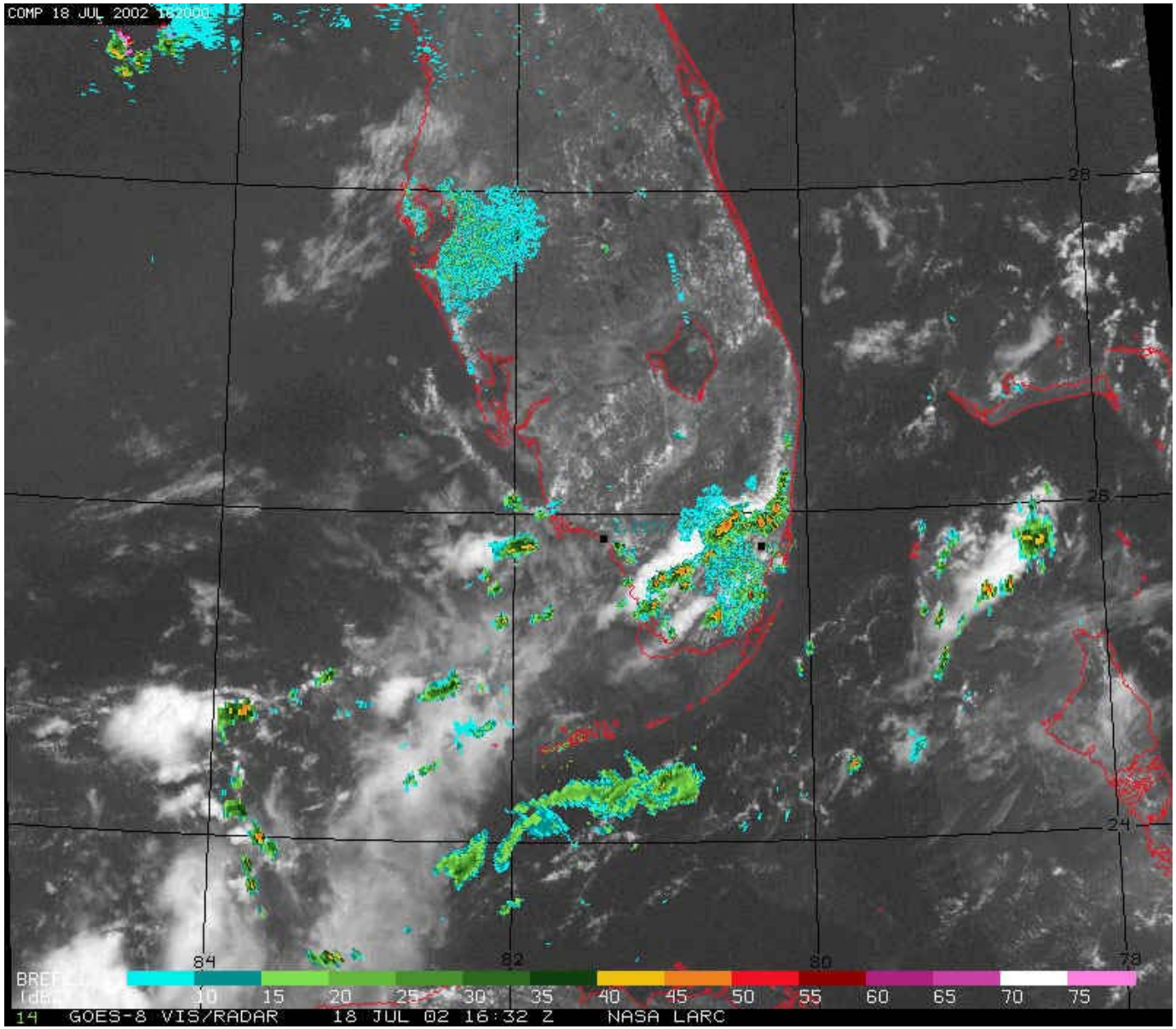
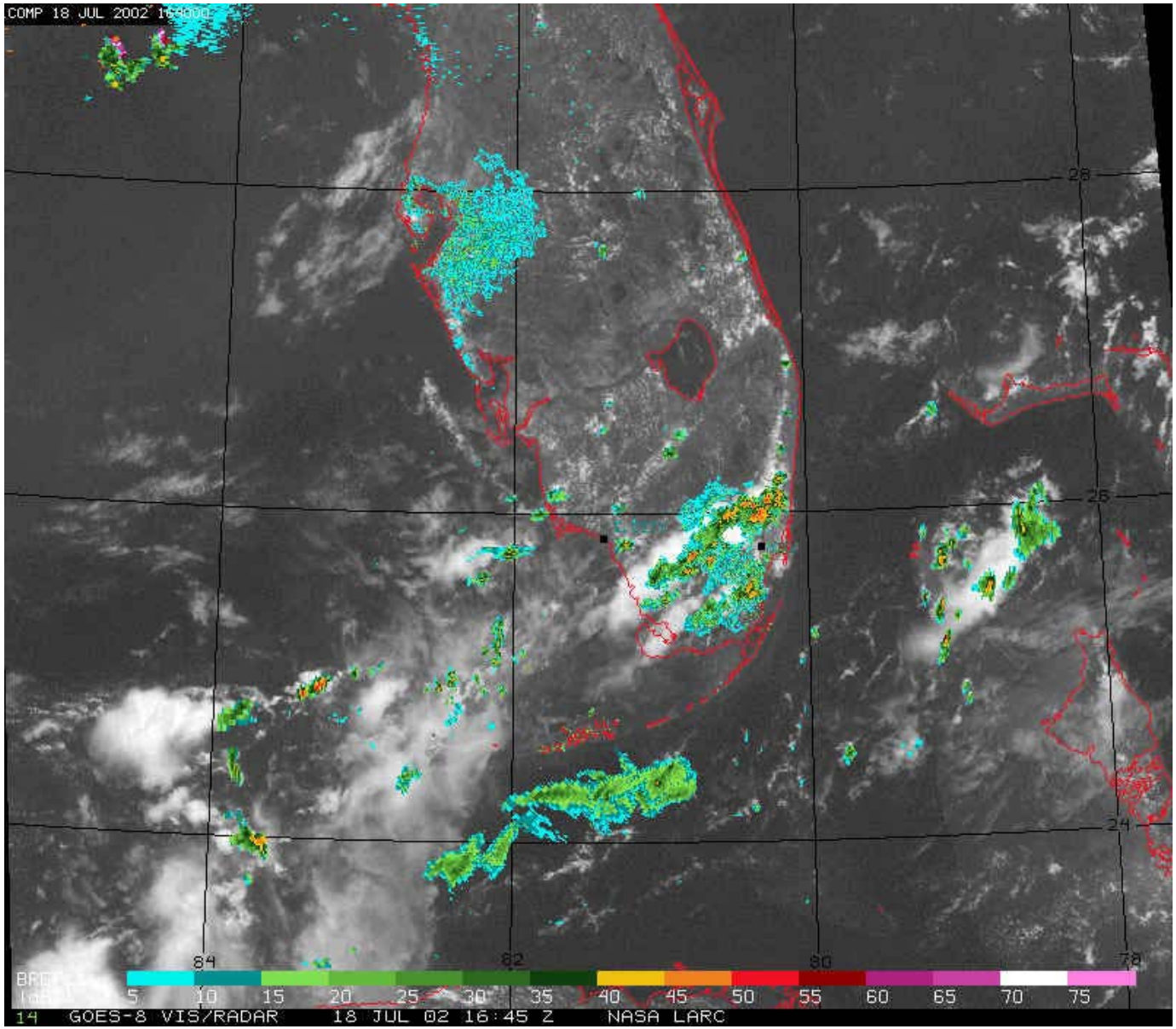
Motivation

- Anvil crystals are formed in strong updraft cores
  - few observations
  - high experimental uncertainty
  - complex microphysical environment
- Can homogeneous nucleation produce most ice crystals?
- Are boundary layer or free tropospheric aerosols more important?
- Is Hallett-Mossop ice multiplication important?
- Is heterogeneous ice nucleation important?

July 18 case study



July 18 case study



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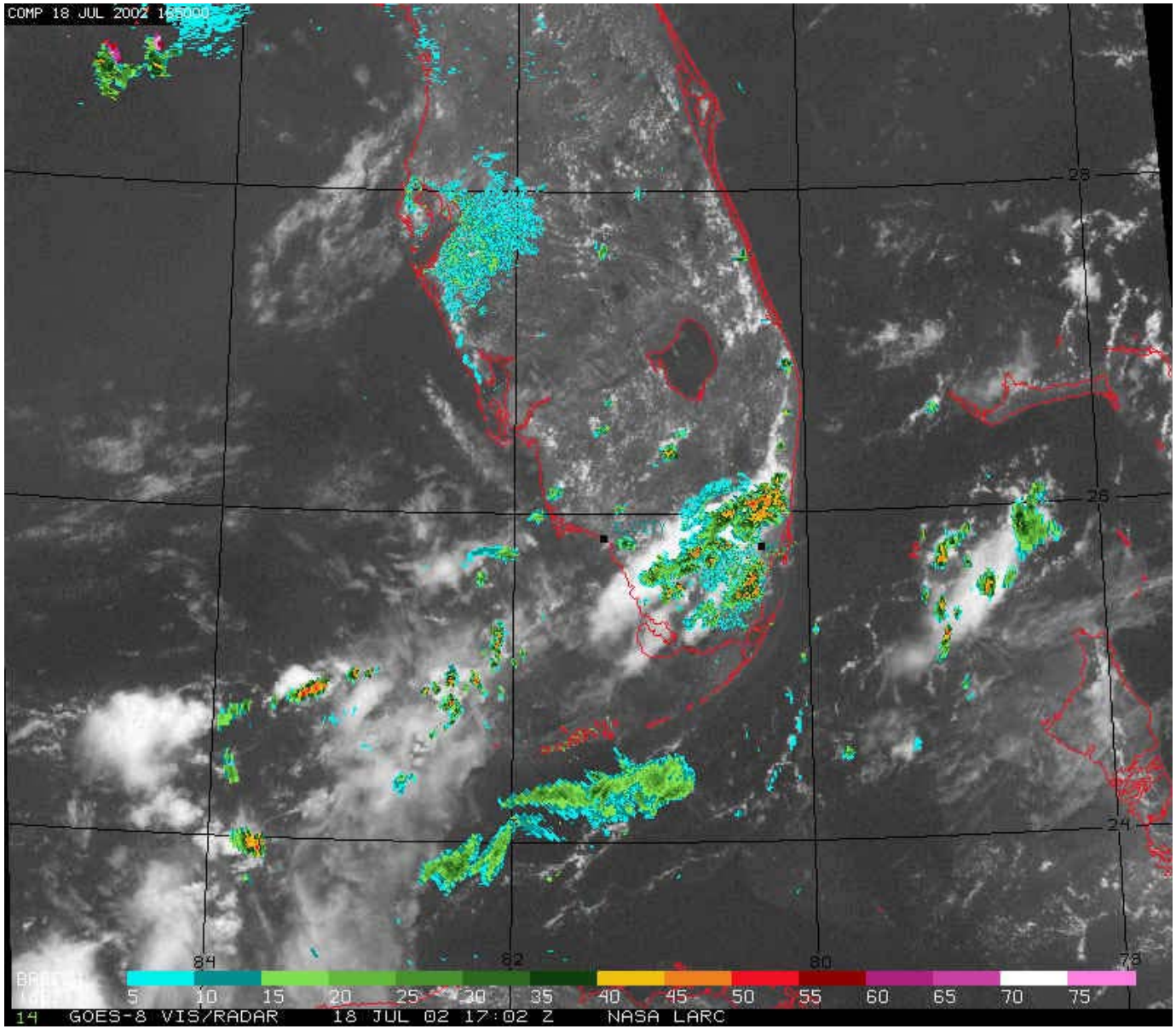

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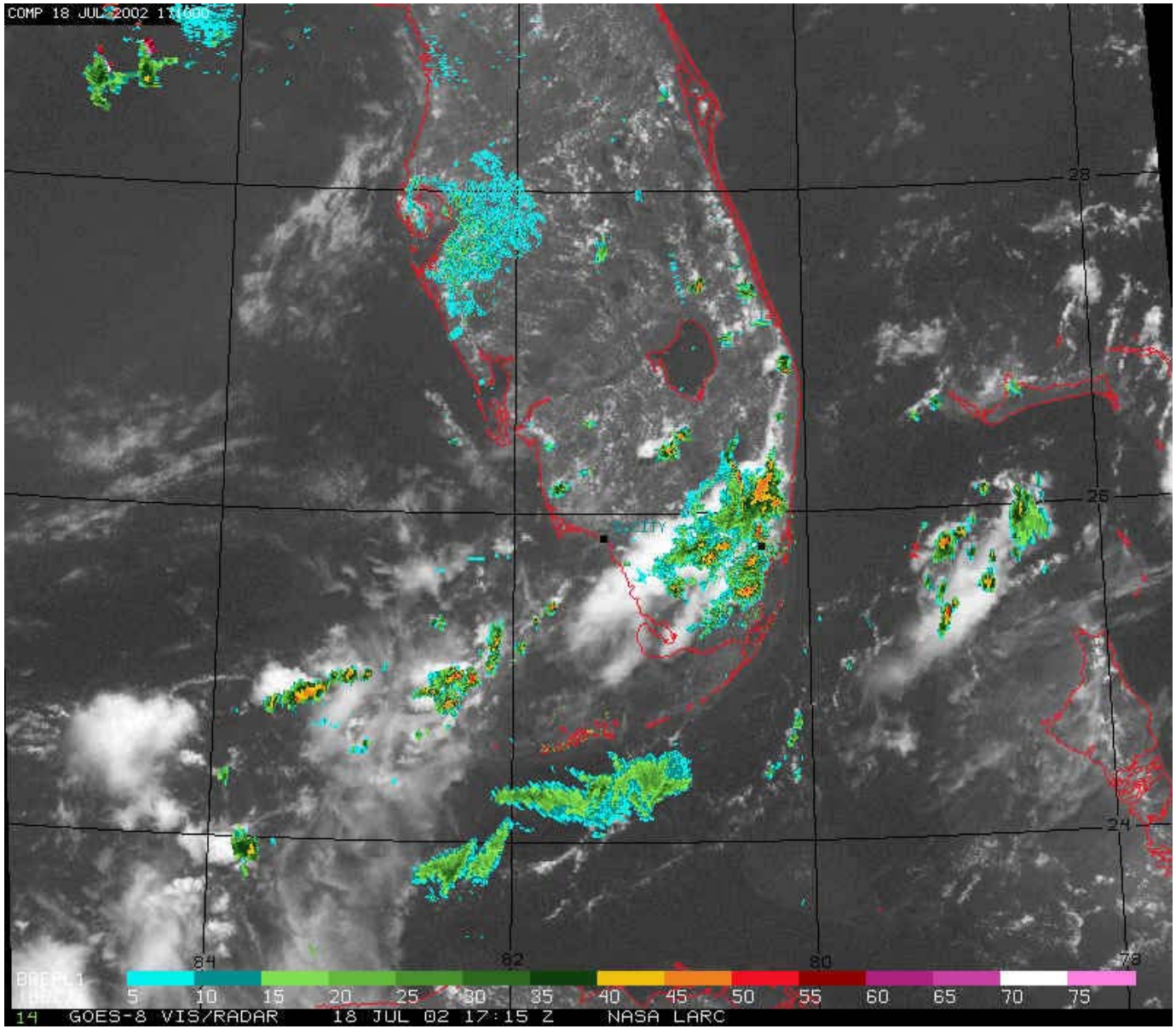

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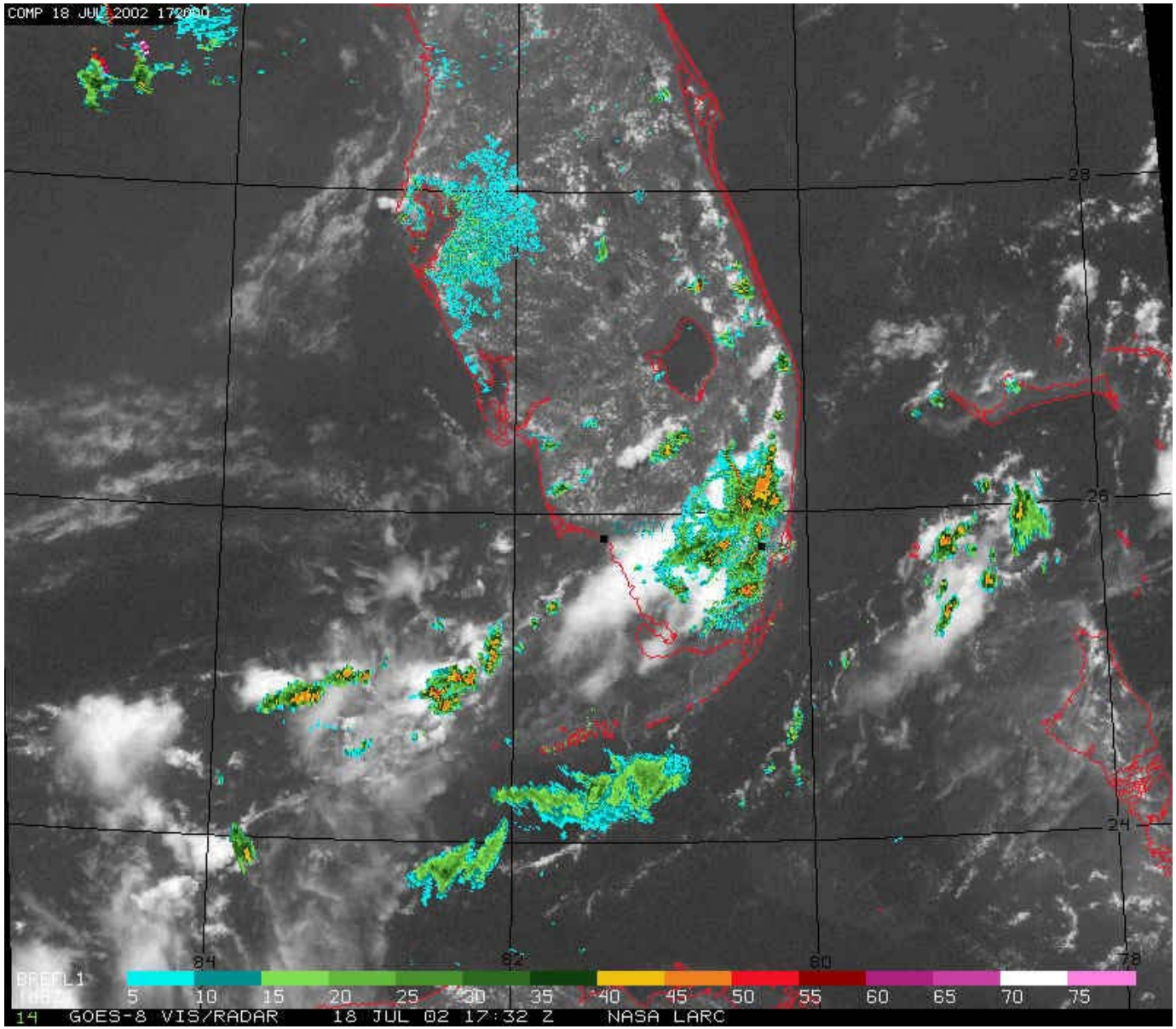

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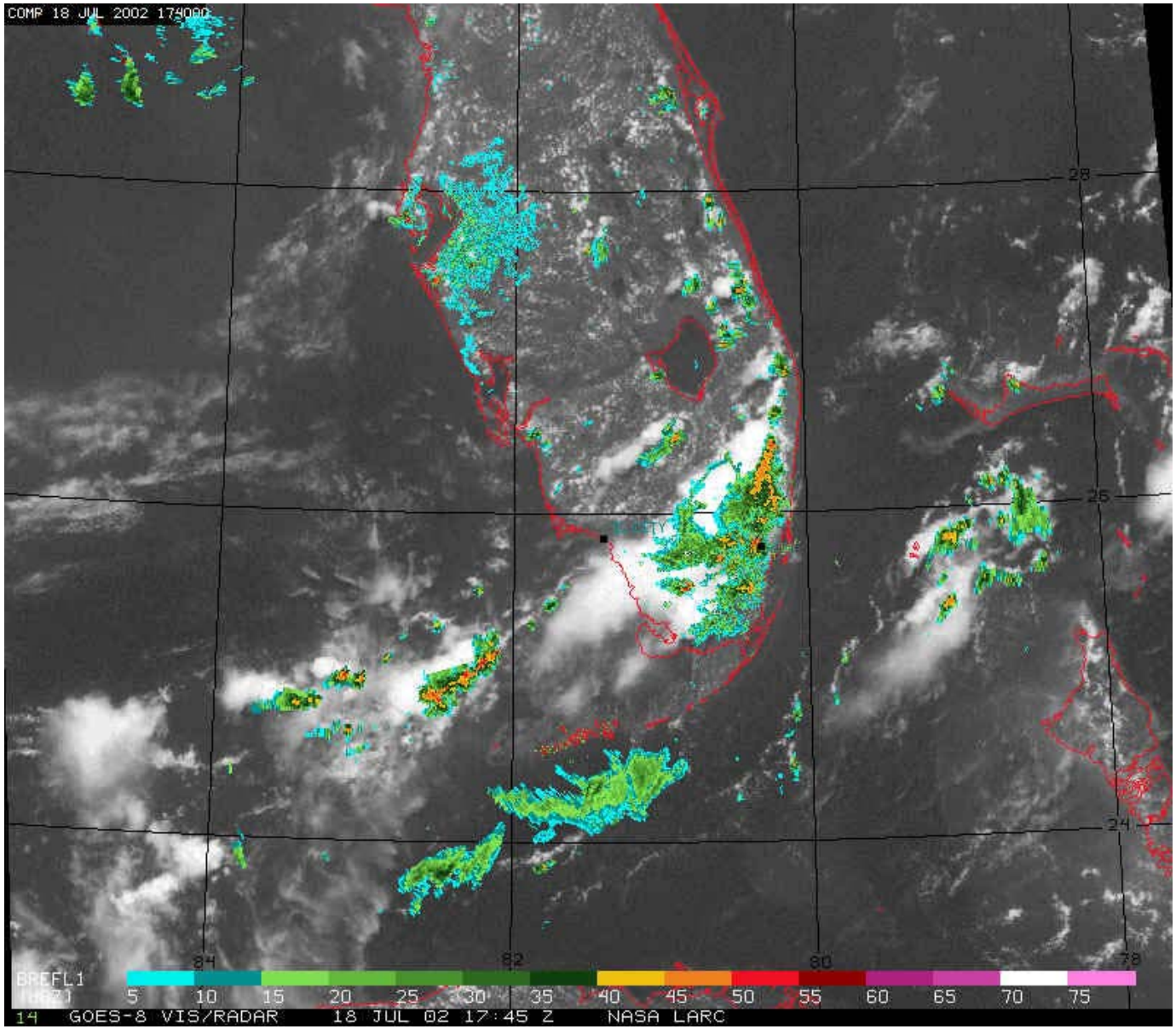

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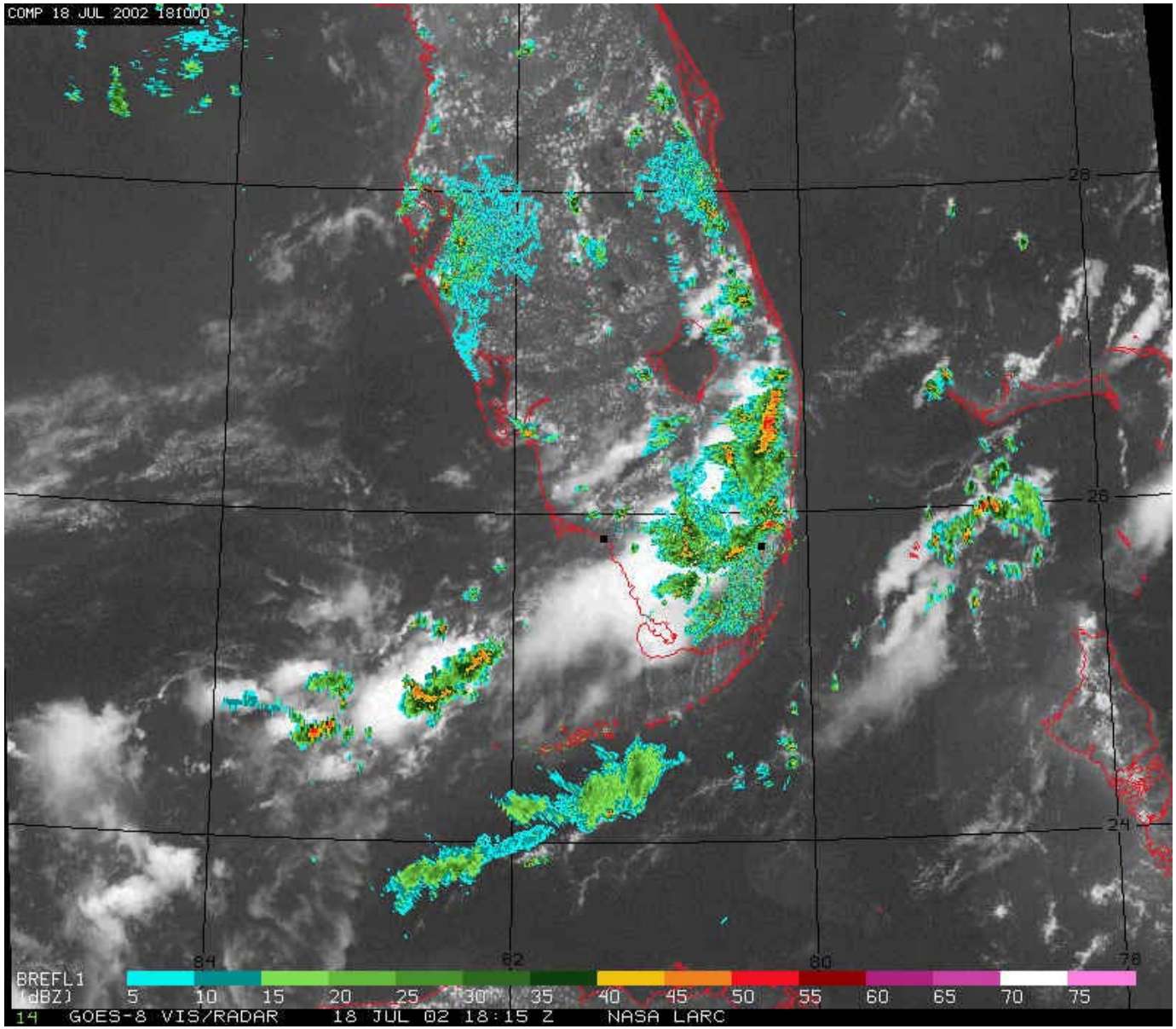
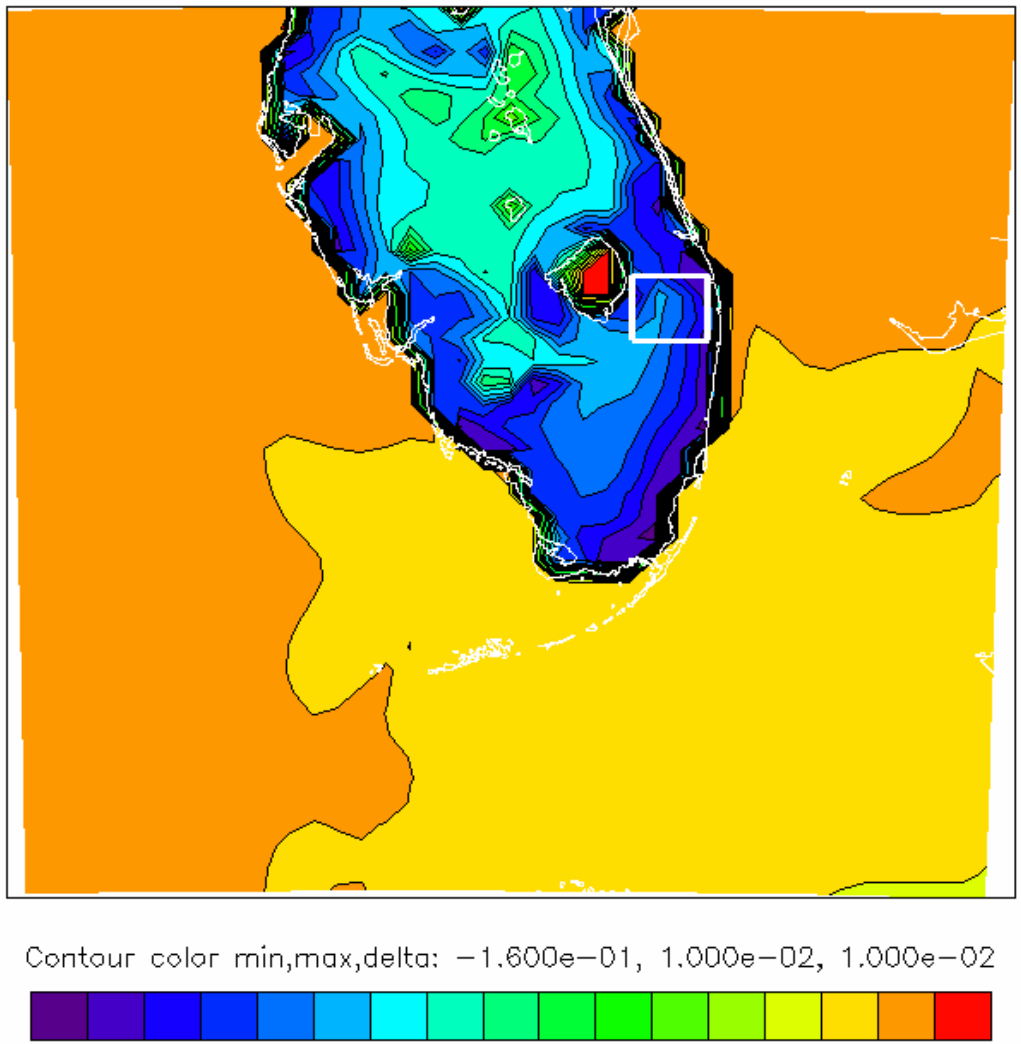


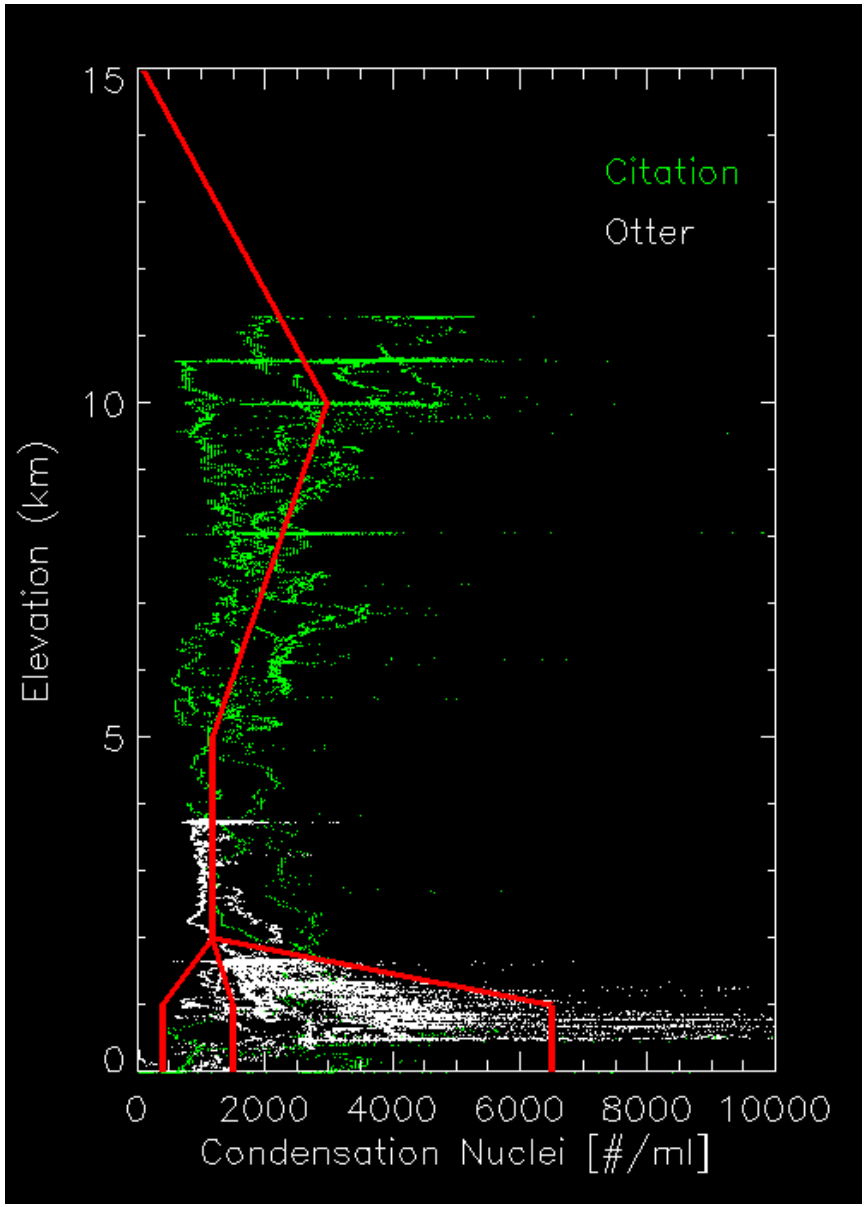
DHARMA model description

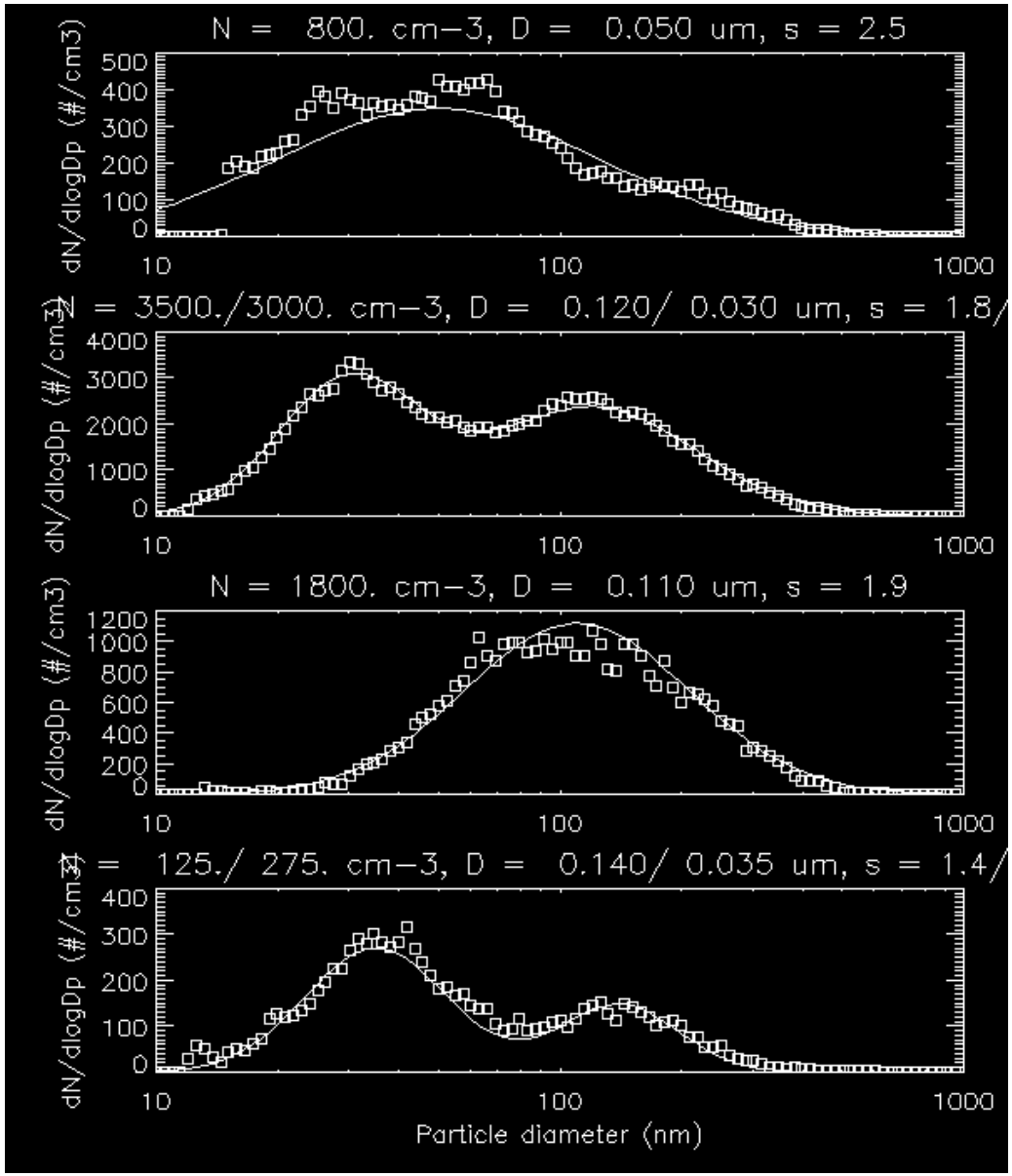
- Domain resolution
  - 48 x 48 x 24 km
  - dx = dy = 500 m, dz = 375 m
- Large-eddy simulation dynamics, dt = 5 s
  - open boundary conditions
  - assimilated meteorology (Miami sounding)
  - assimilated surface fluxes (ARPS model)
- Explicit microphysics, minimum dt = 0.2 s
  - 16 bins: aerosols (20 nm -1 um), liquid and ice (2 um ->1cm)
  - aerosol activation/freezing, condensation/evaporation, coagulation, breakup, homogeneous/heterogeneous ice nucleation, Hallett-Mossop ice multiplication

Assimilated surface fluxes: ARPS model

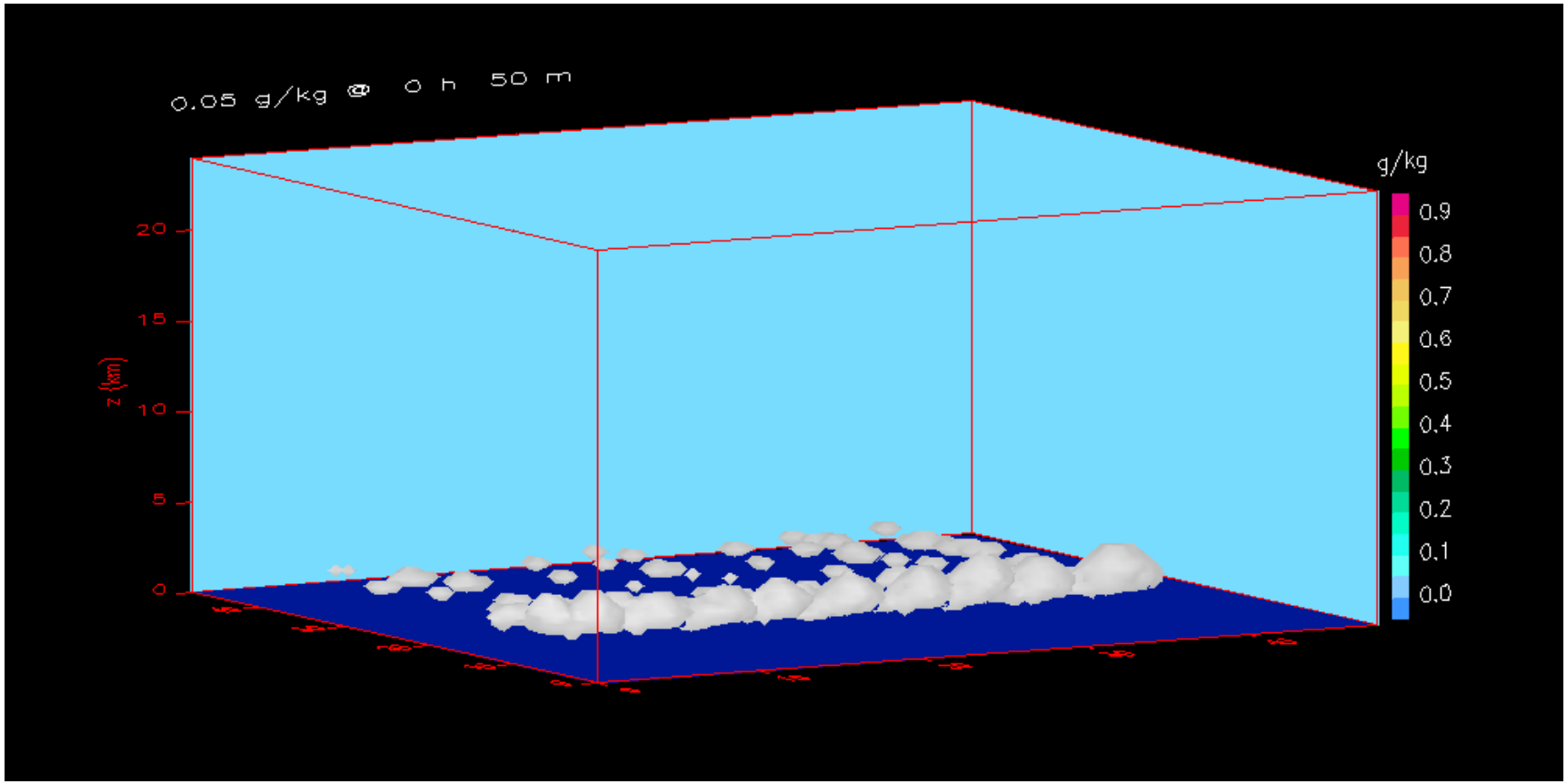


Assimilated aerosol profiles: Twin Otter and Citation





Modeled cloud isosurface



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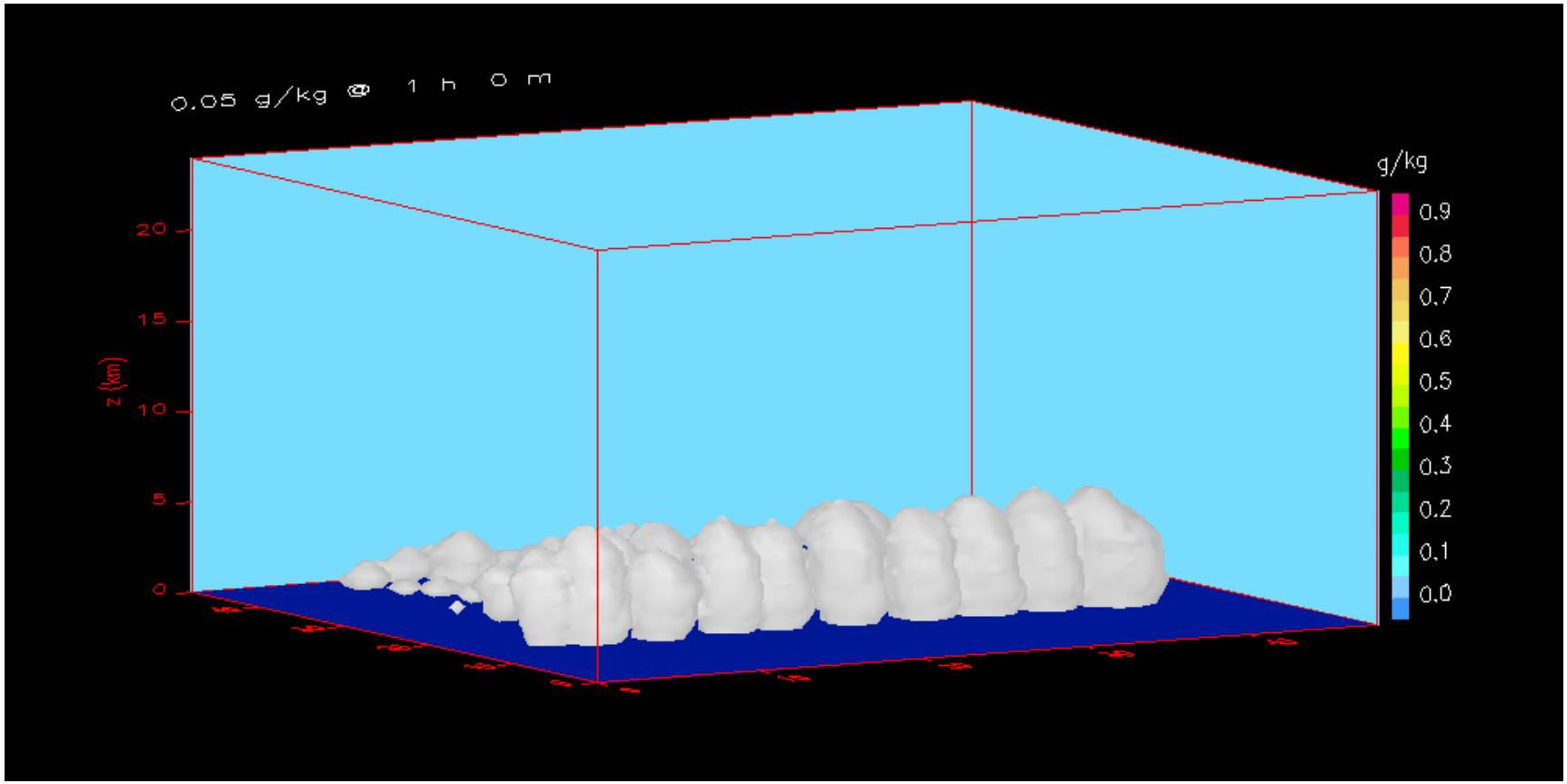
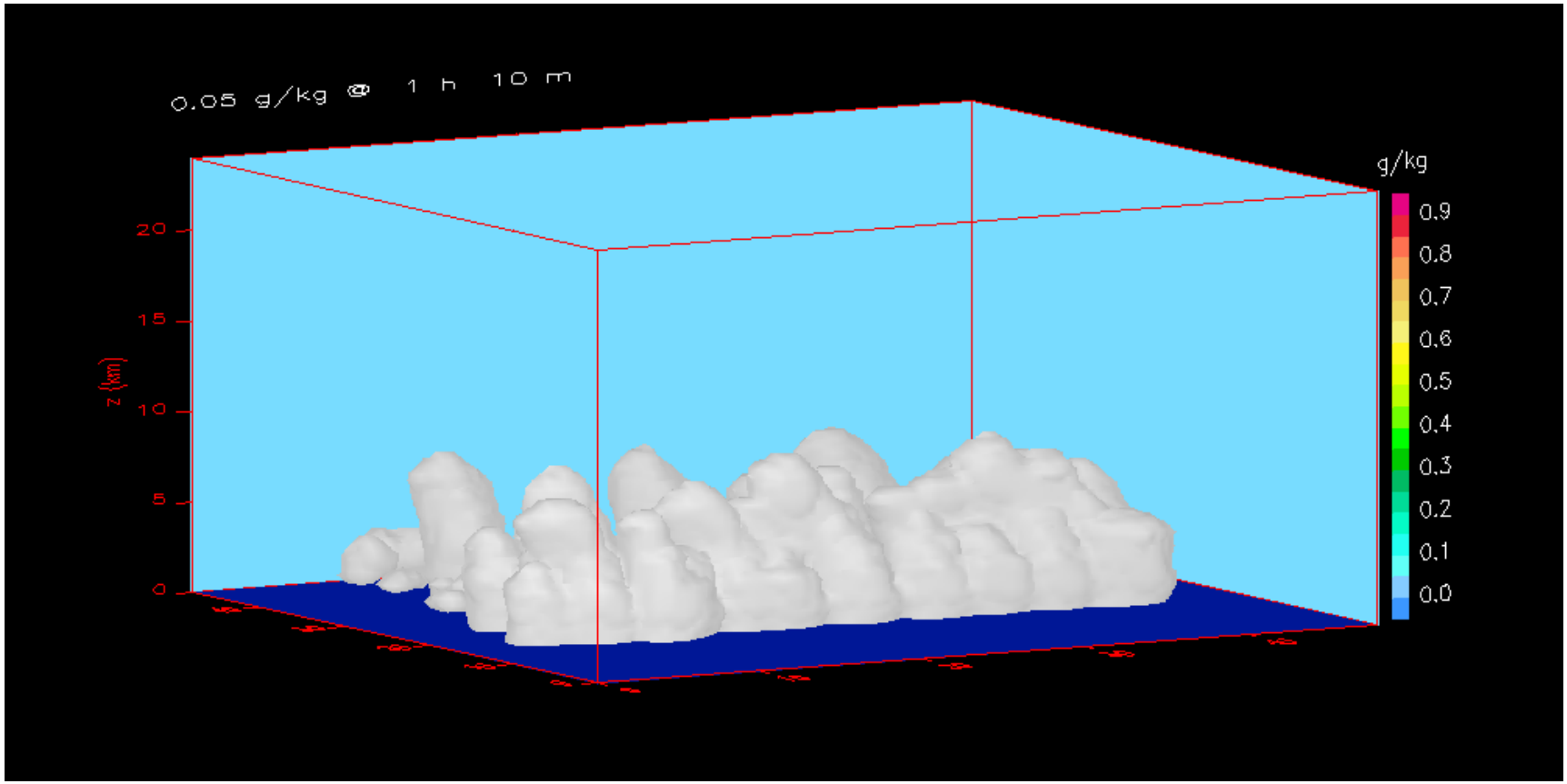
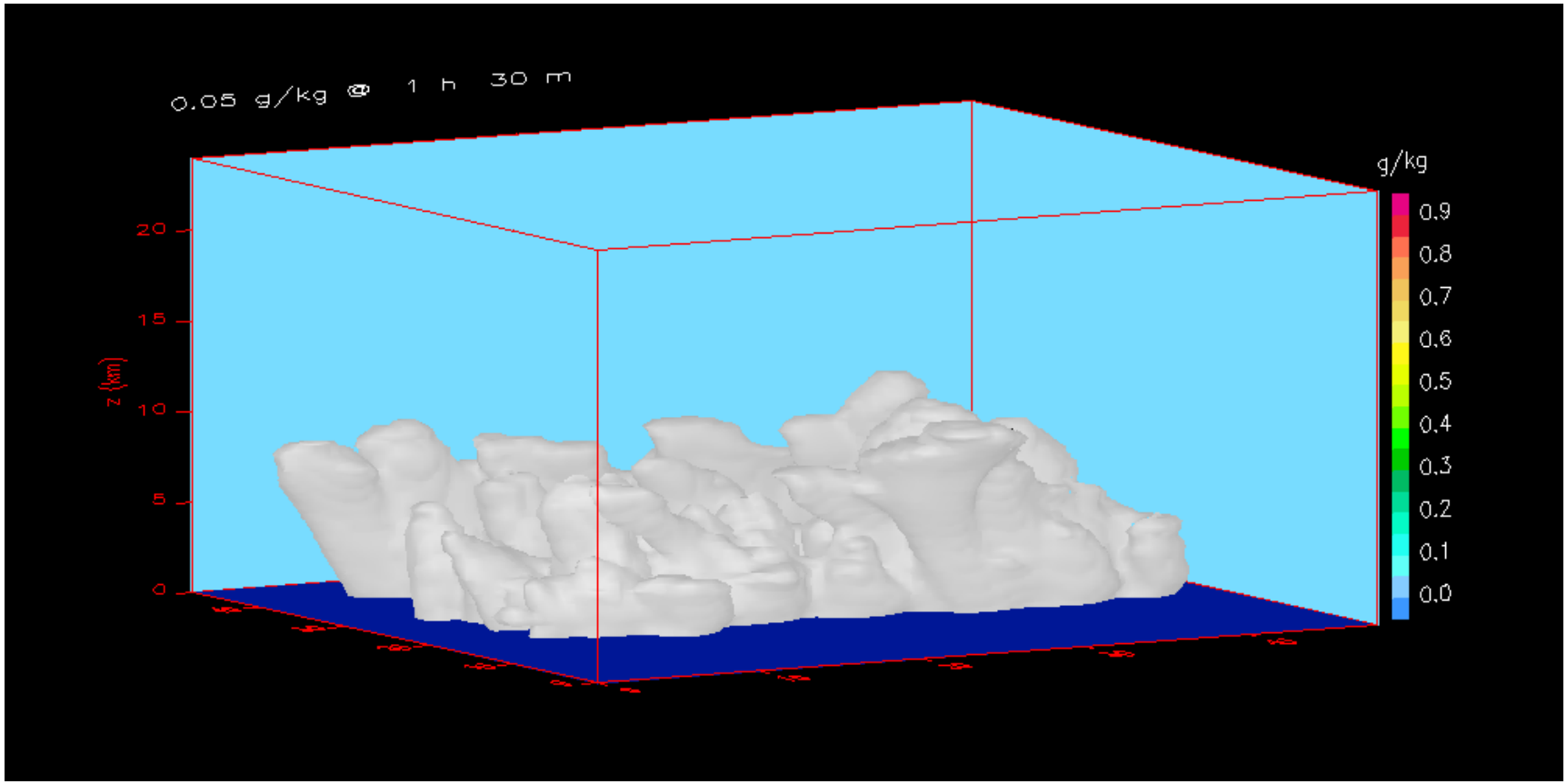


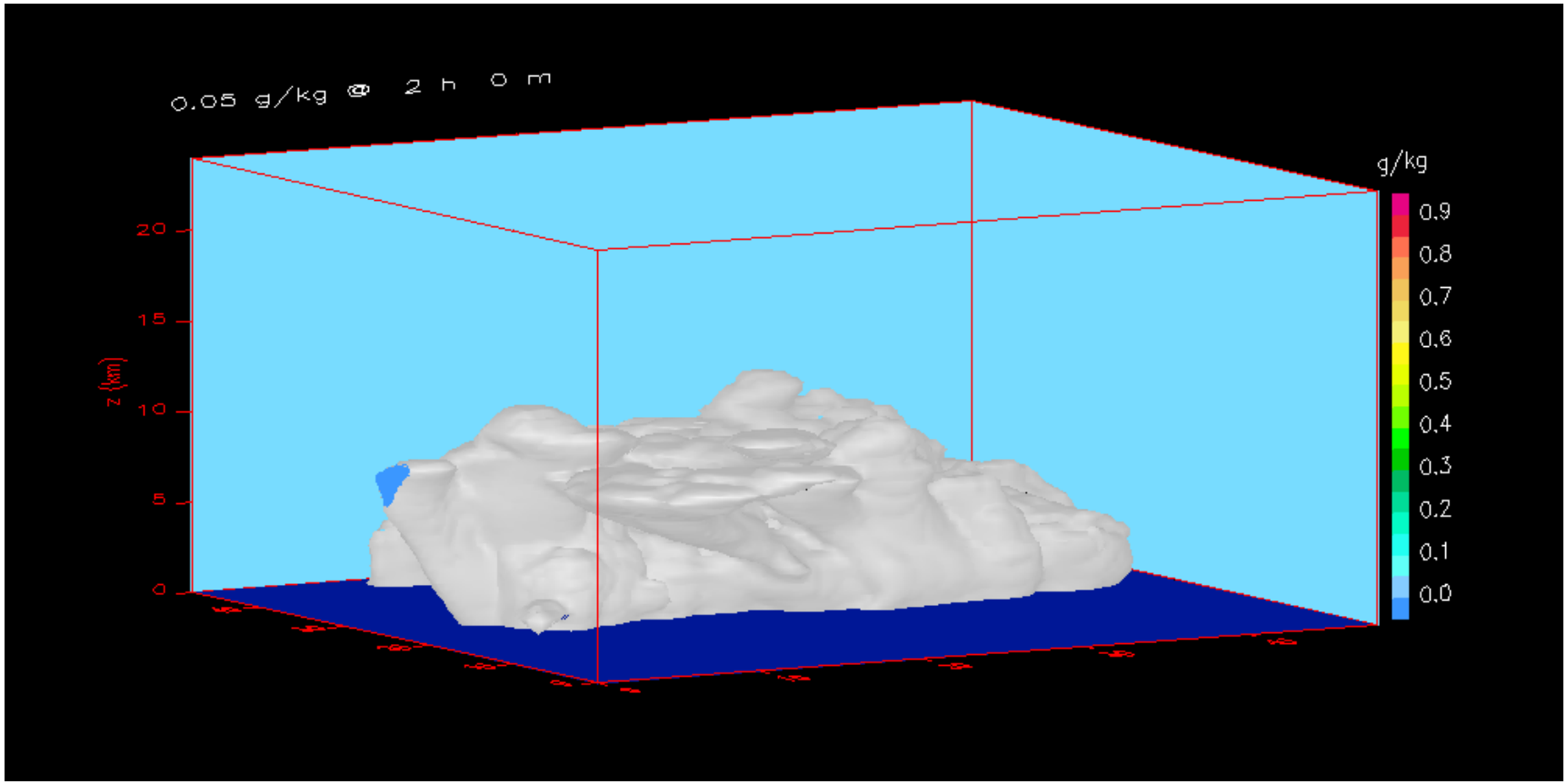
Modeled cloud isosurface



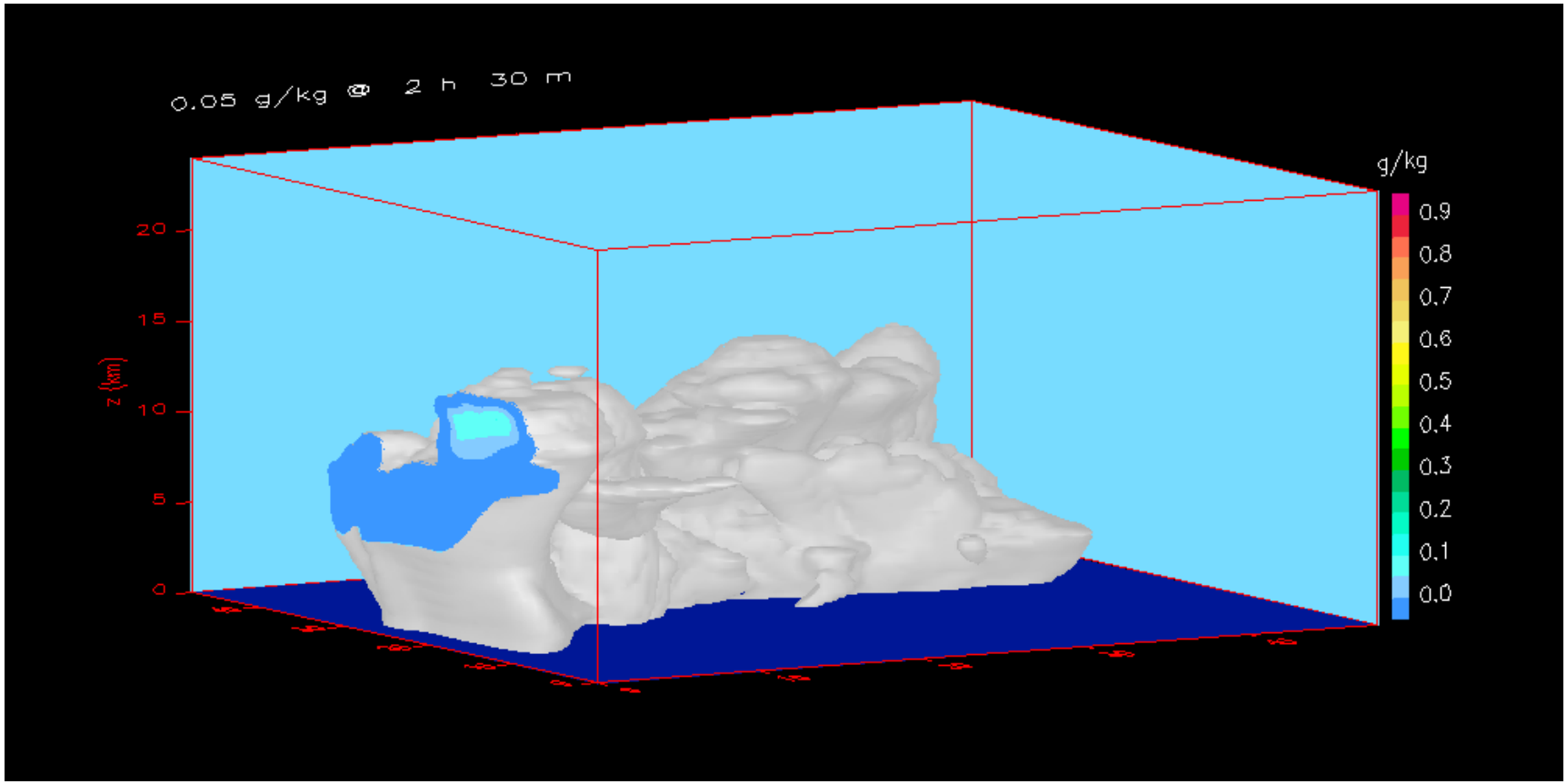
Modeled cloud isosurface



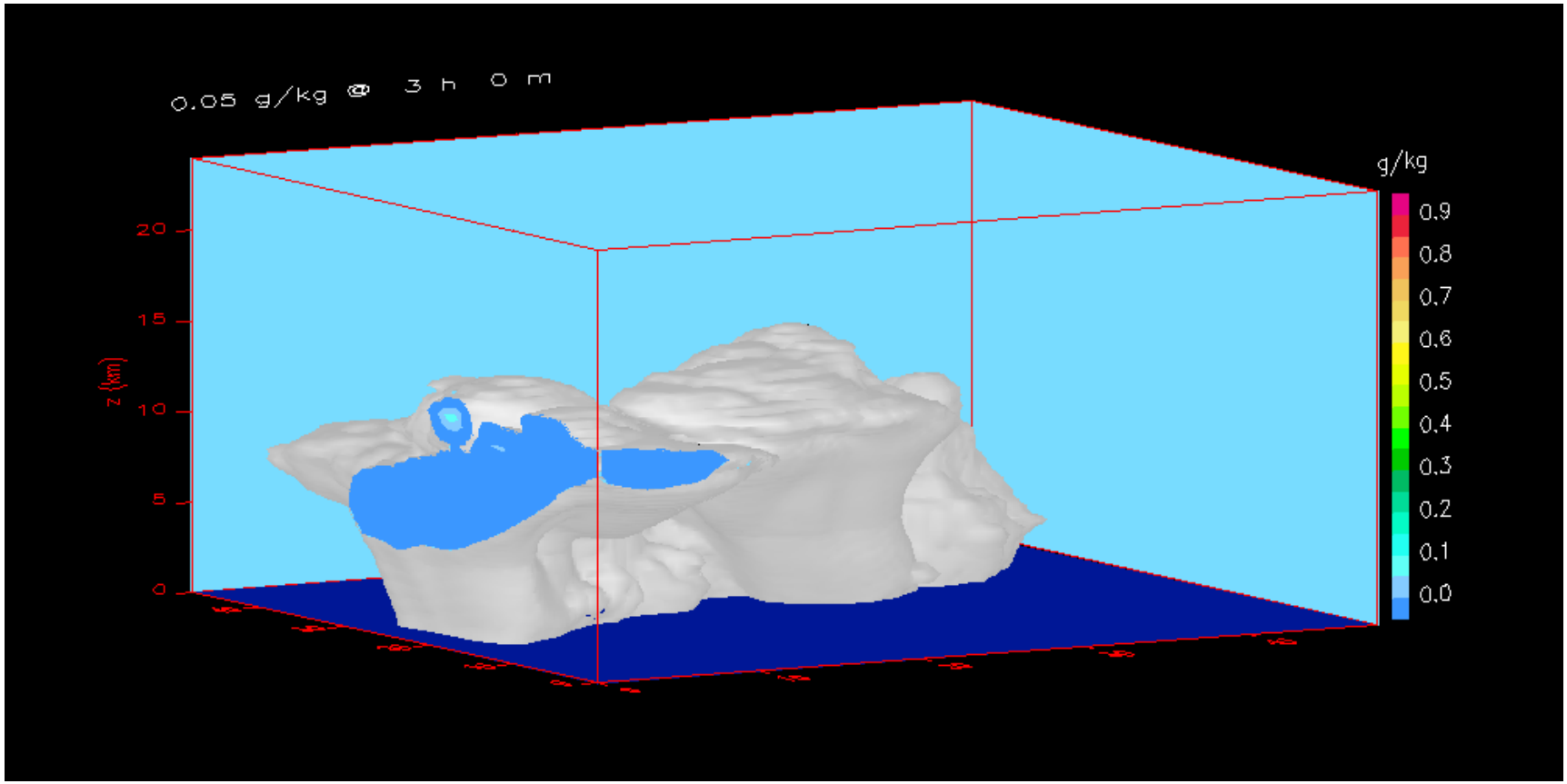
Modeled cloud isosurface



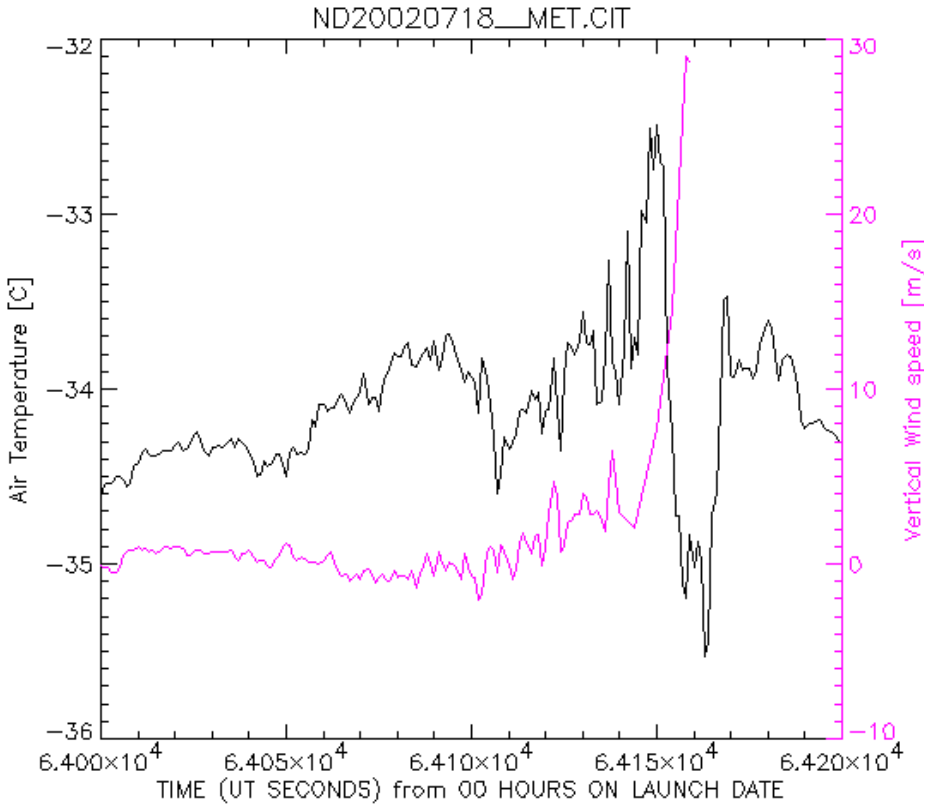
Modeled cloud isosurface

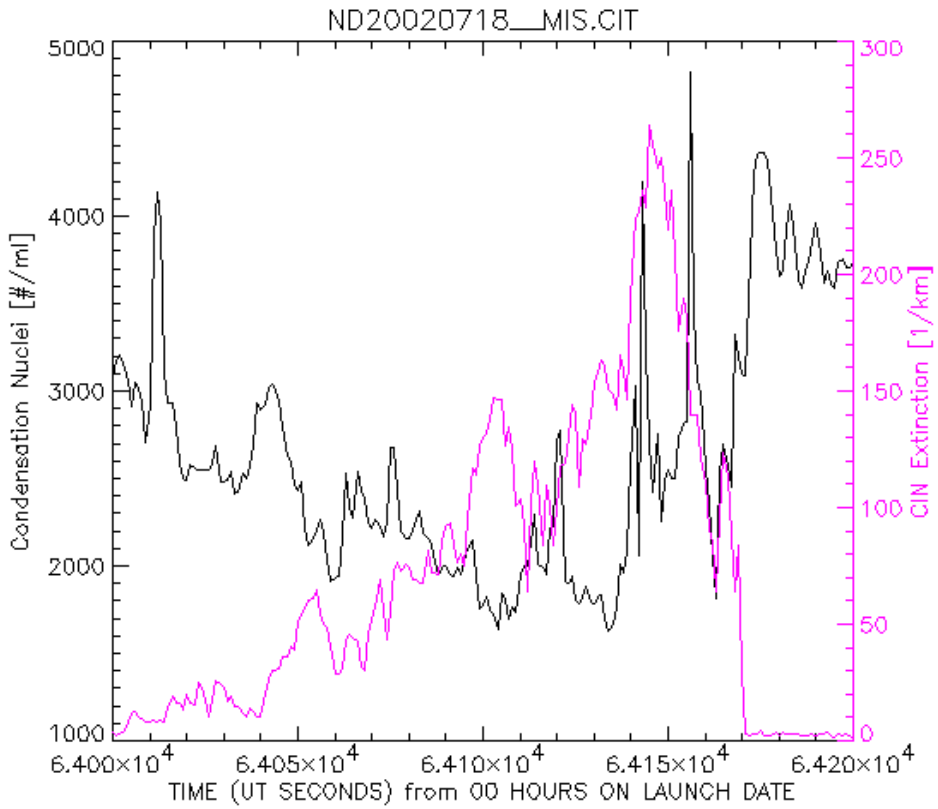


Modeled cloud isosurface



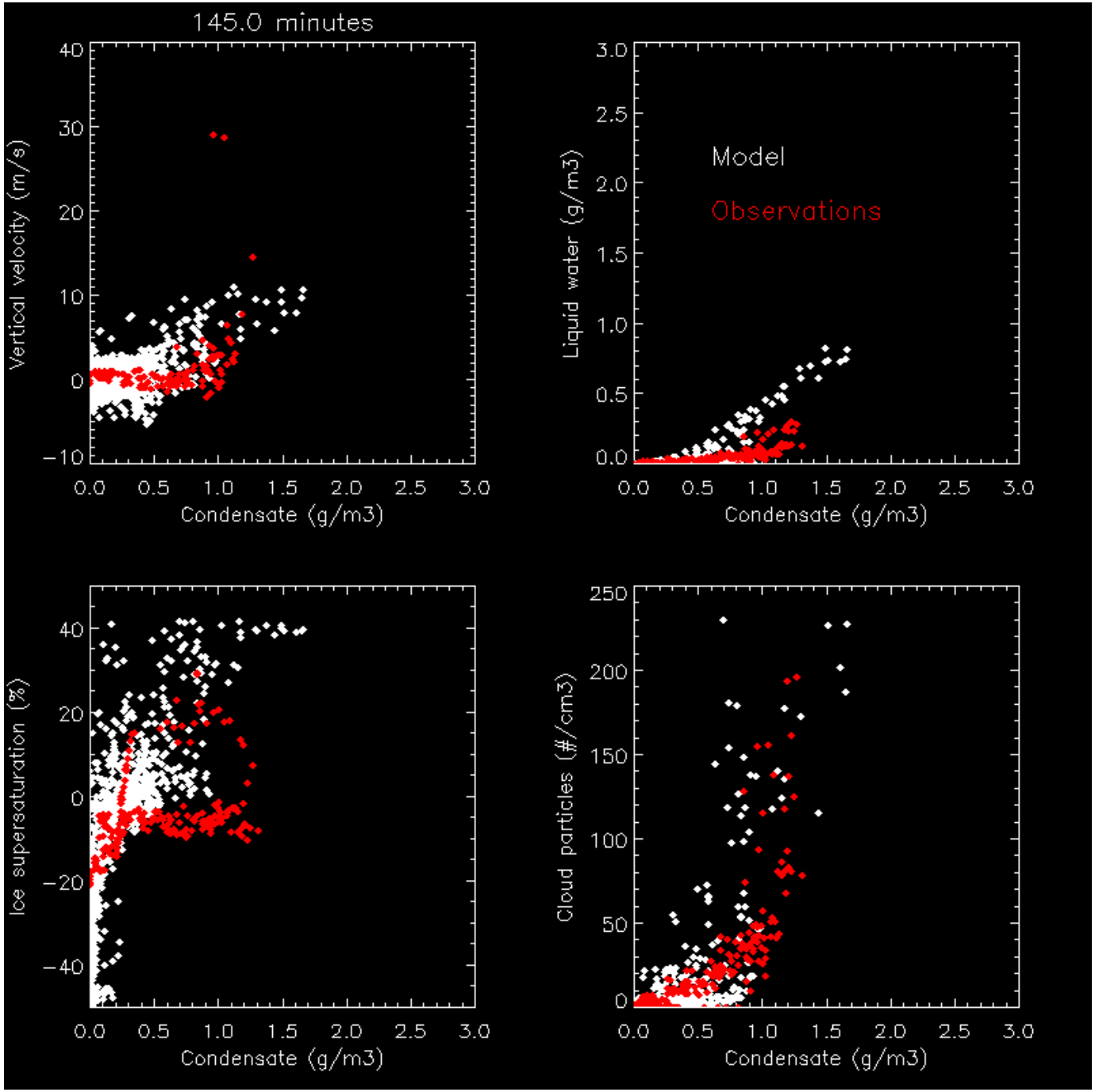
Citation flight data



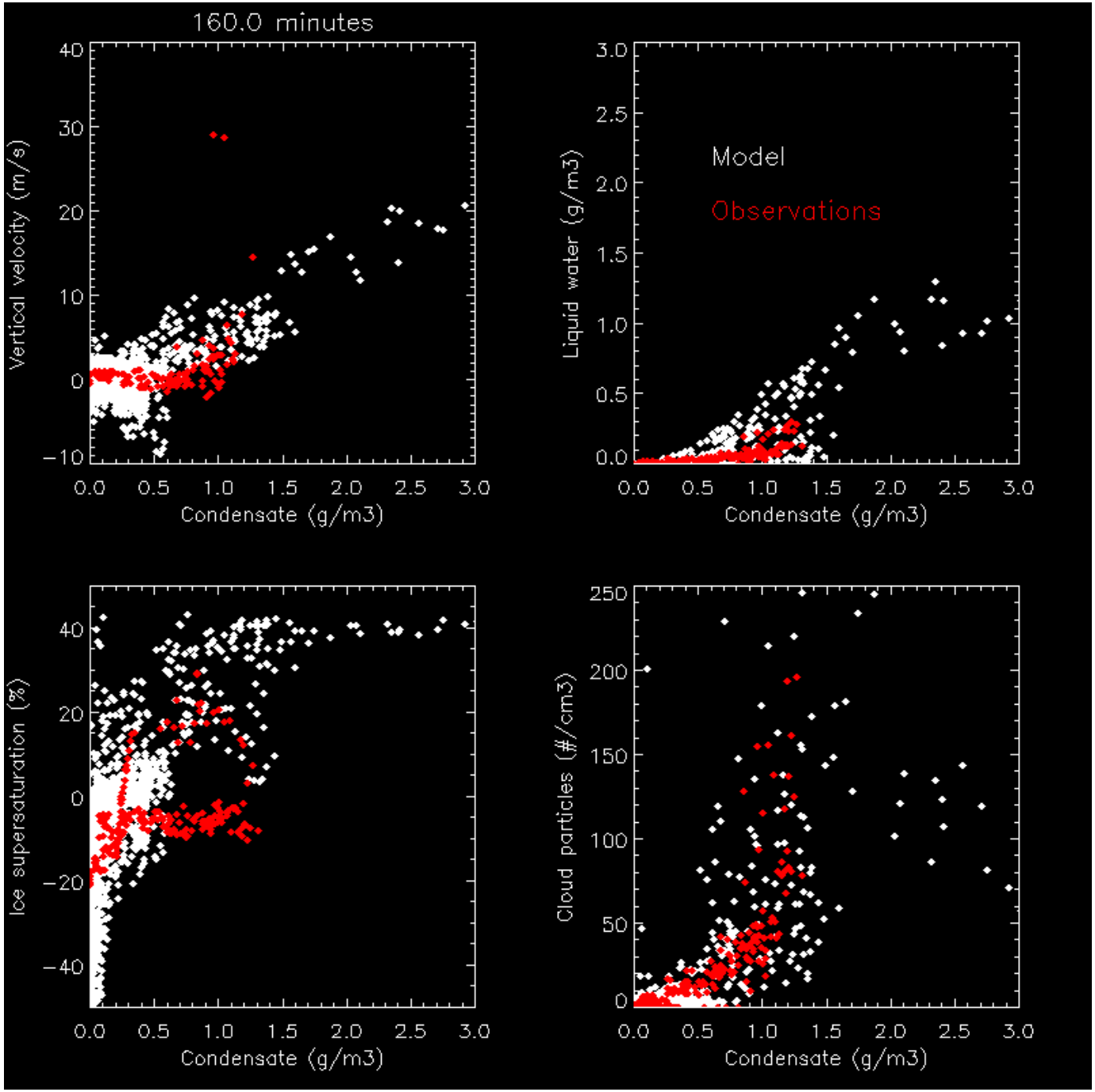


Can homogeneous nucleation produce most ice crystals?

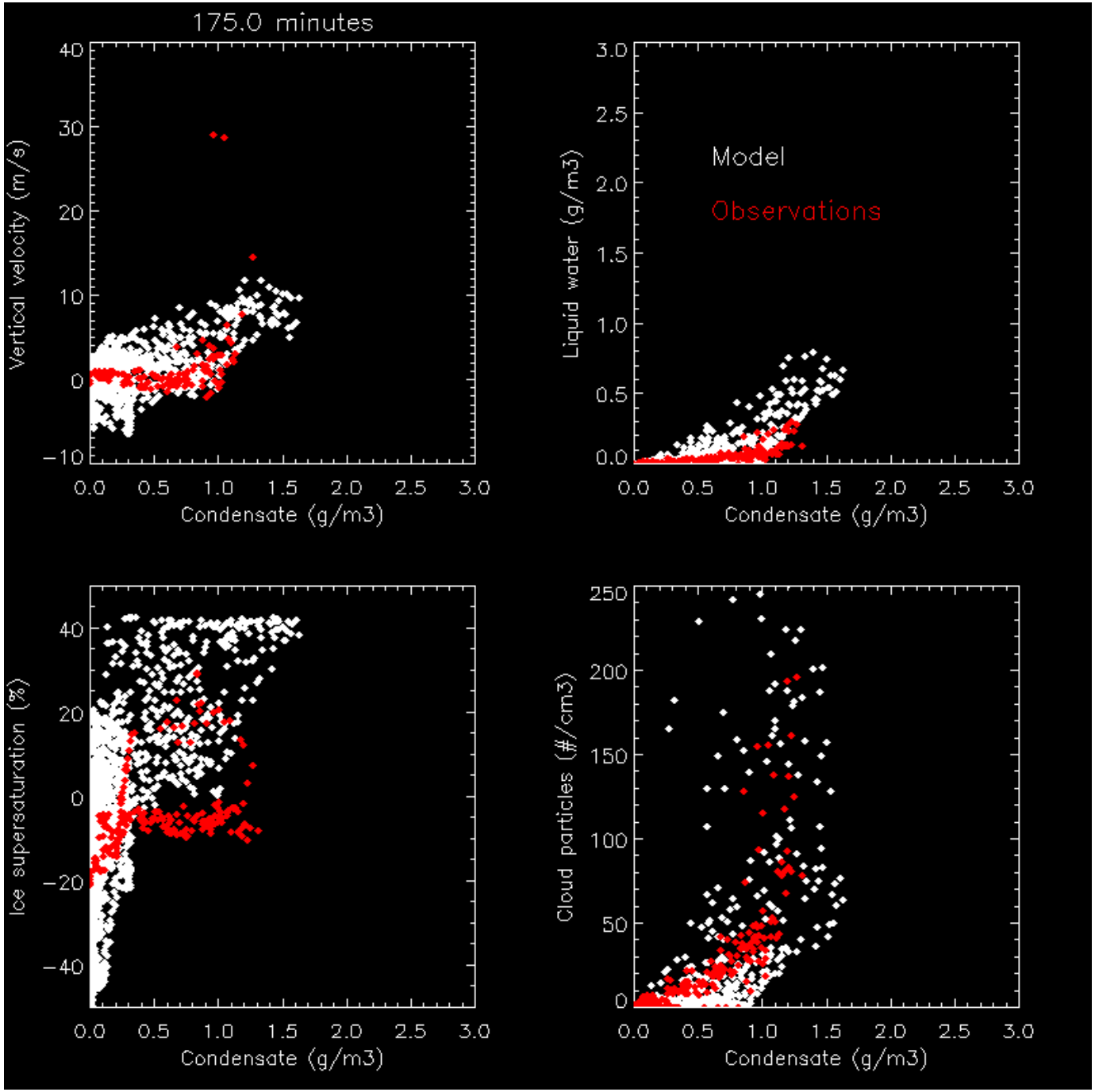
Observations versus model layer at T = -36C



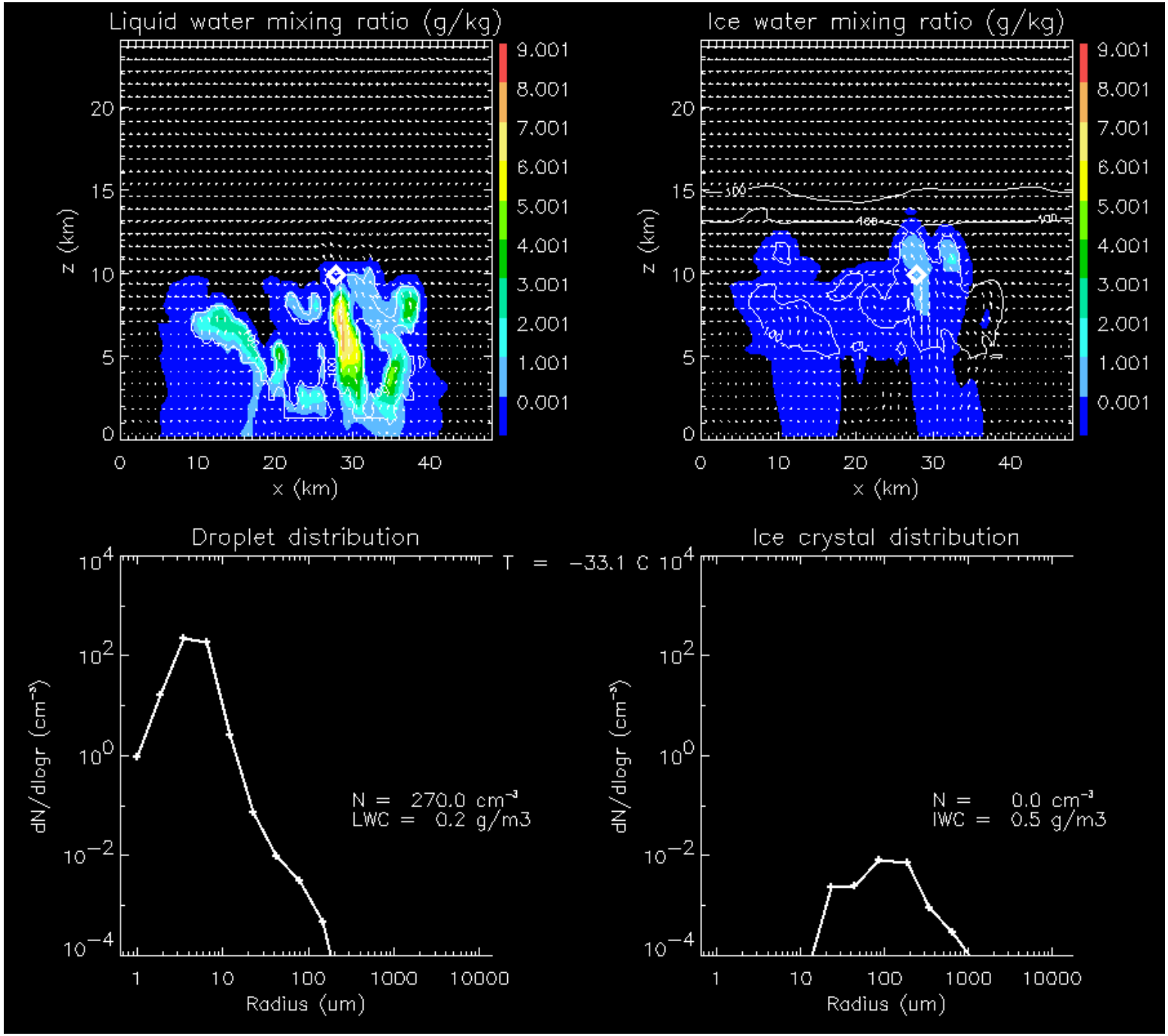
Observations versus model layer at T = -36C



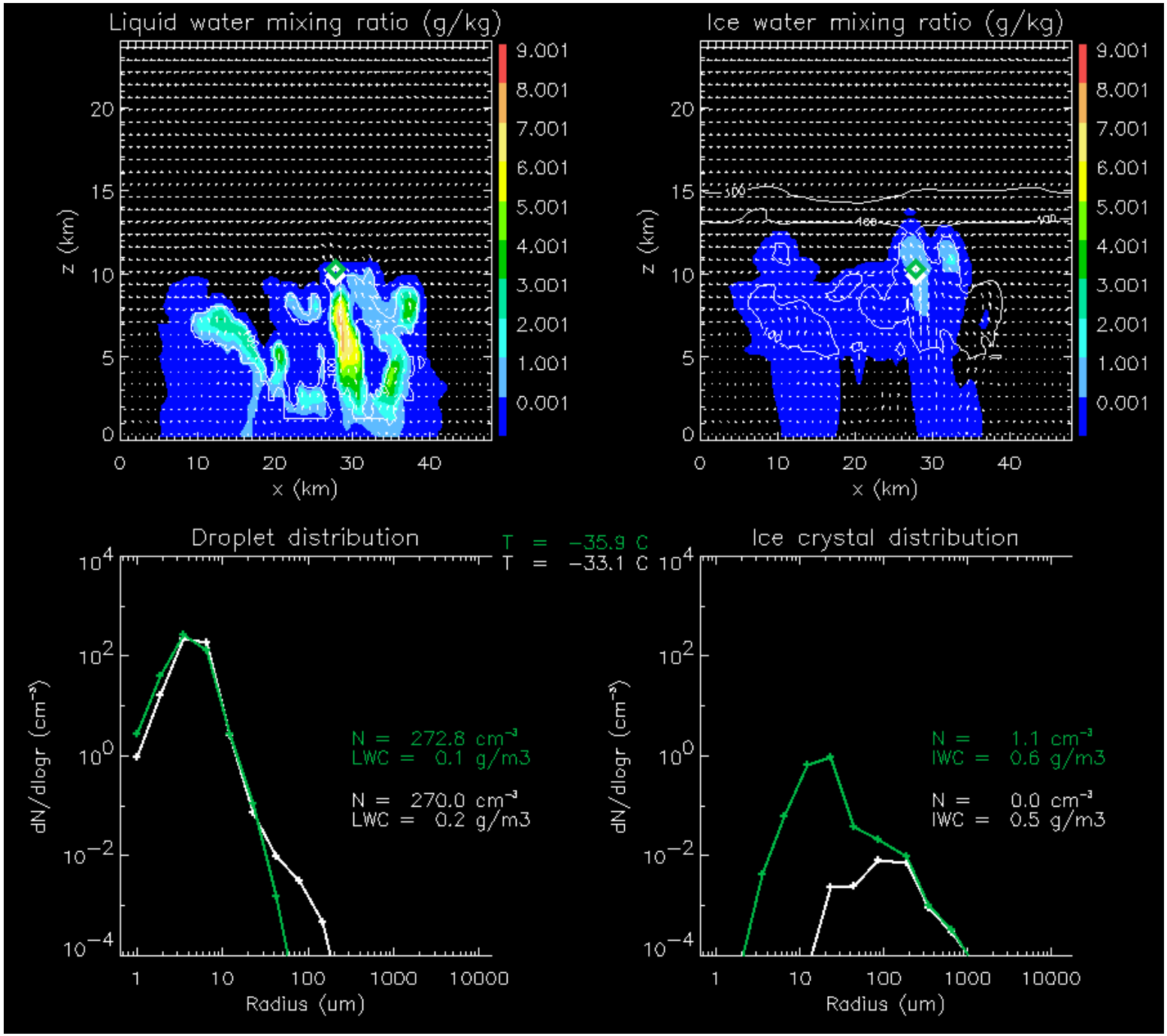
Observations versus model layer at T = -36C



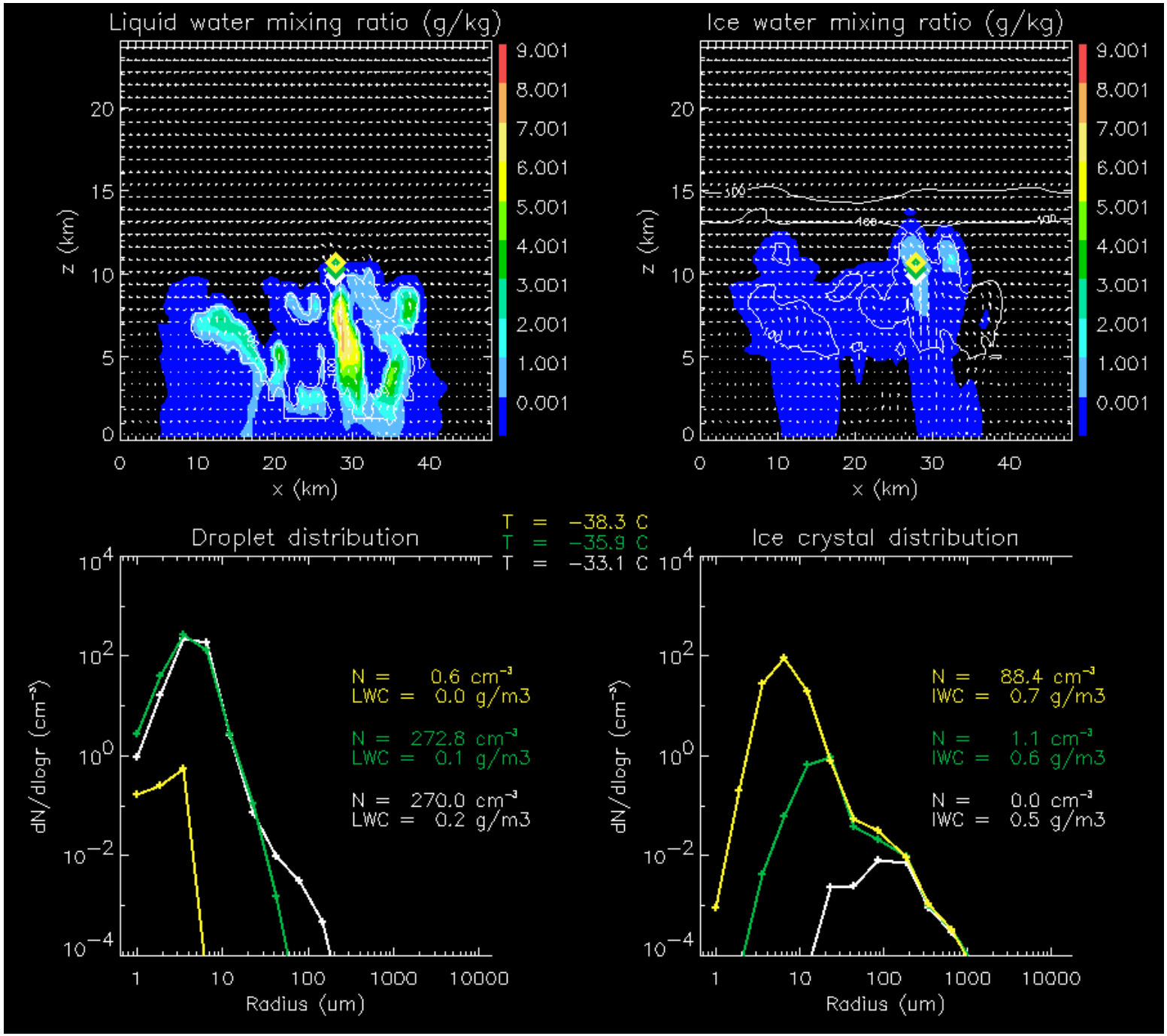
Modeled droplet nucleation within updraft core



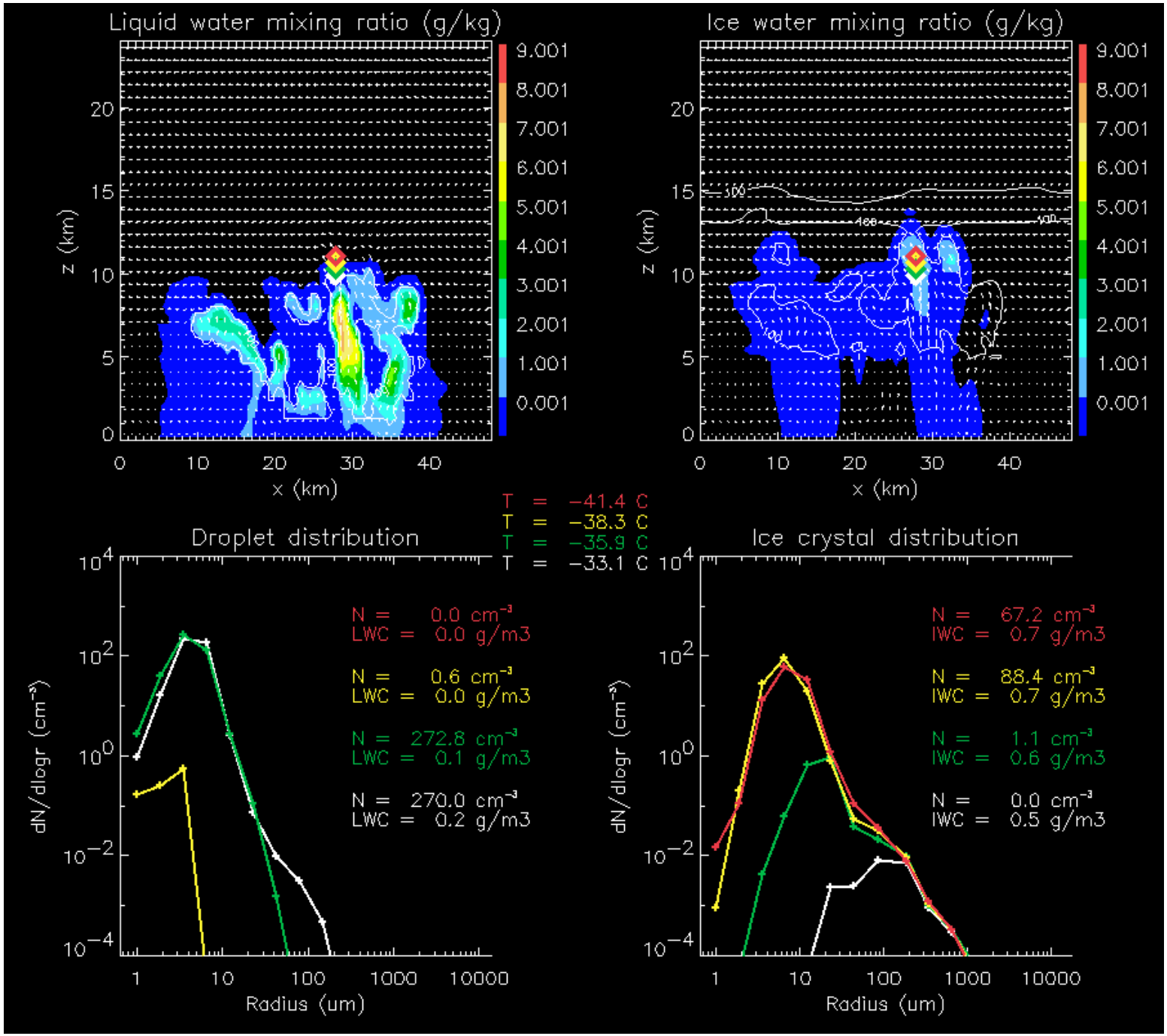
Modeled droplet nucleation within updraft core



Modeled droplet nucleation within updraft core

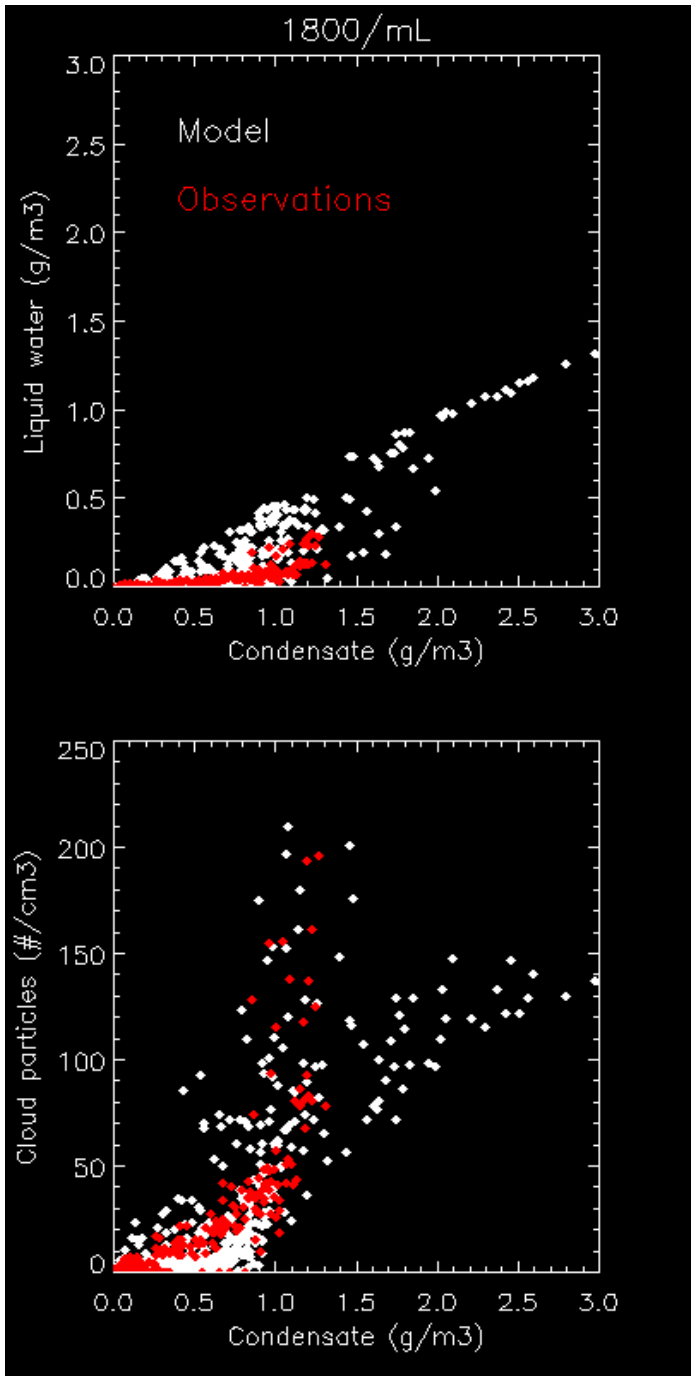


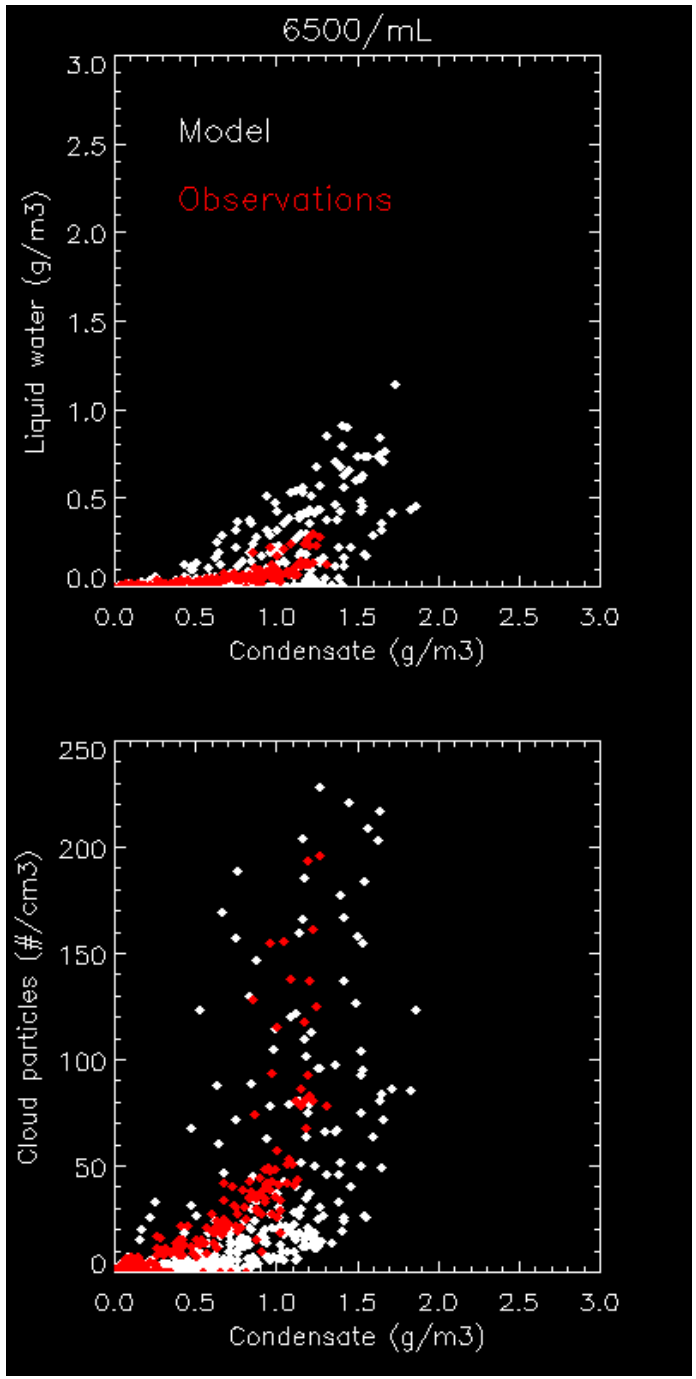
Modeled droplet nucleation within updraft core



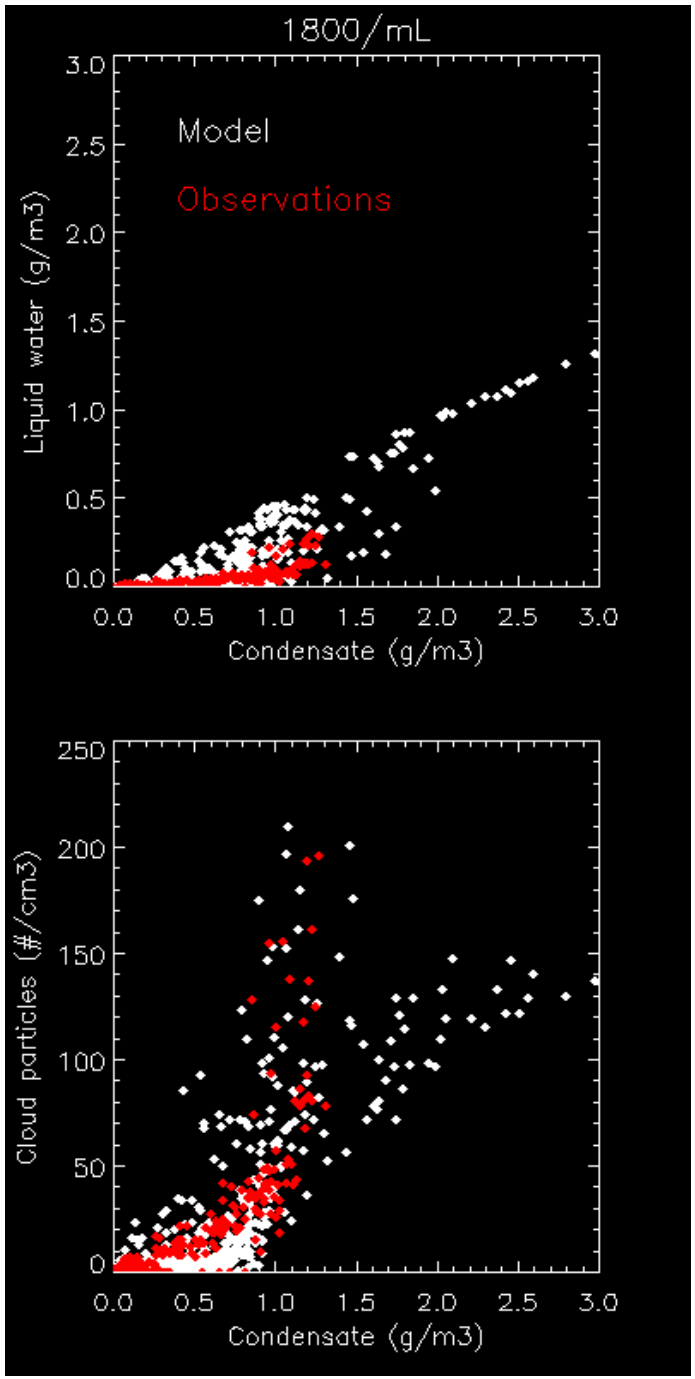
Are boundary layer or free tropospheric aerosols more important?

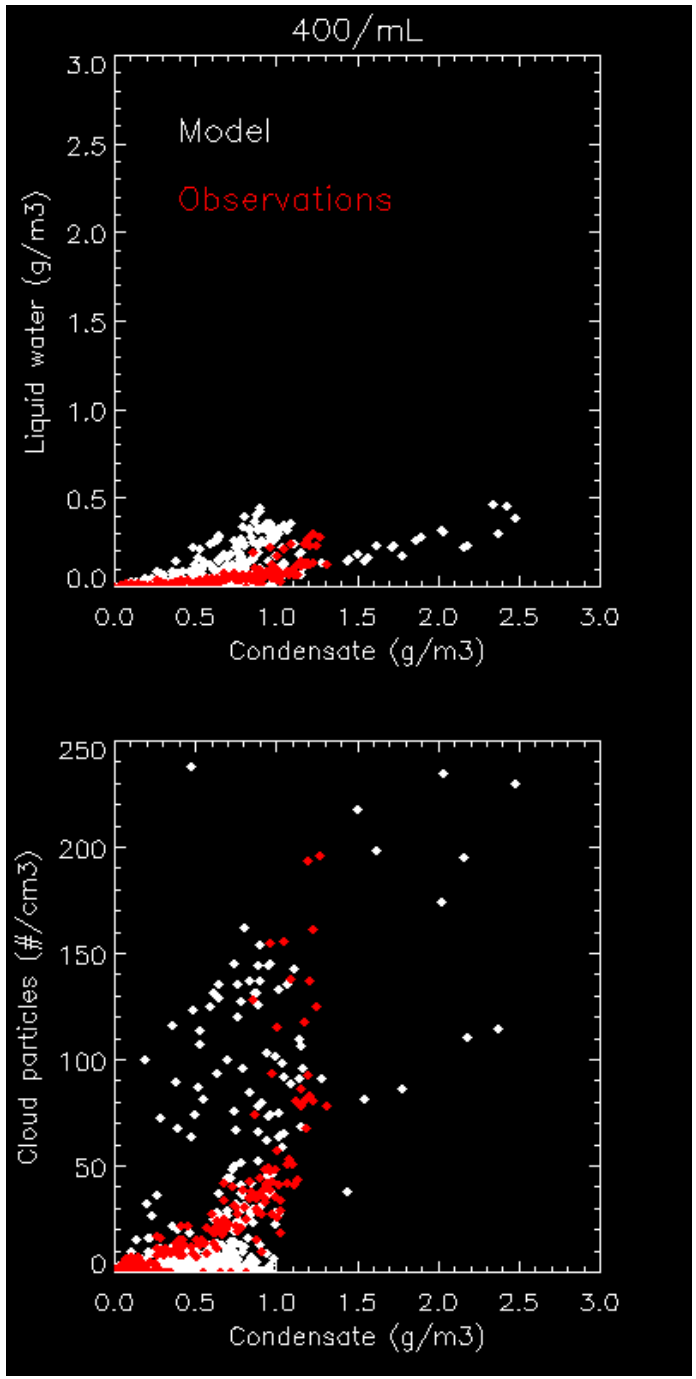
Boundary layer aerosol increased to 6500/mL



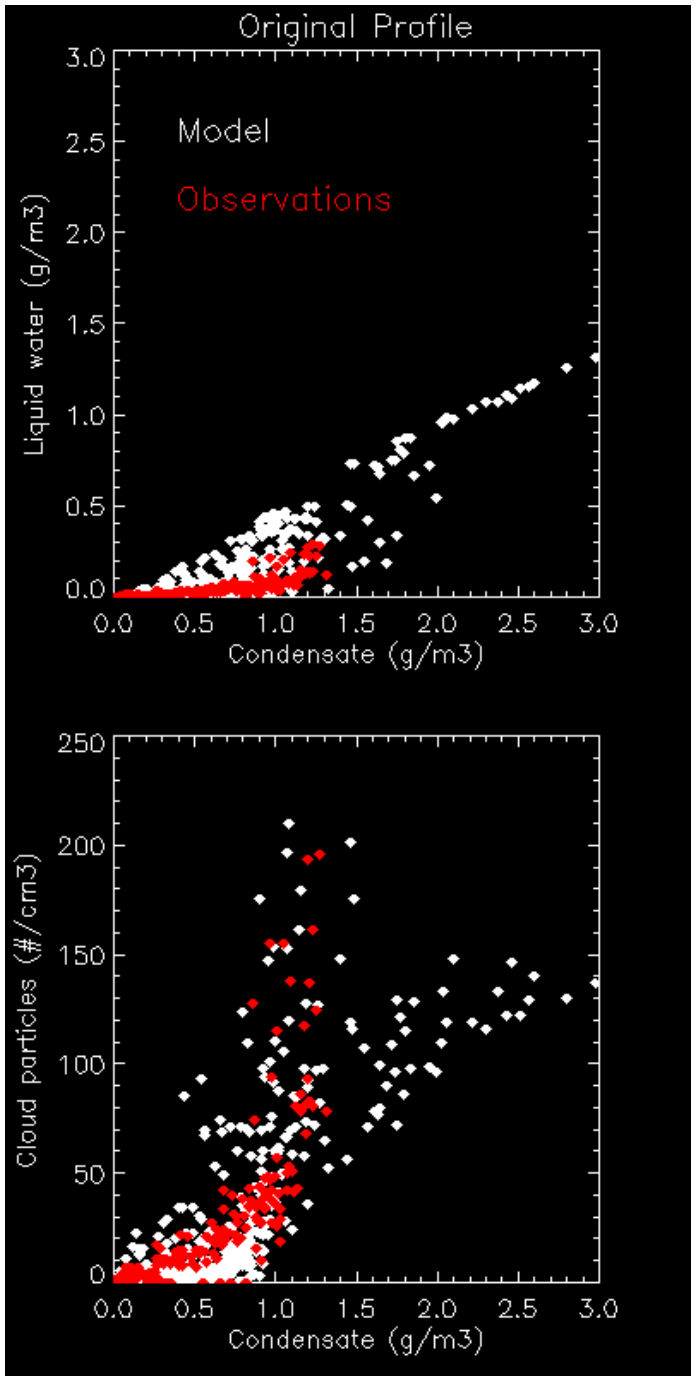


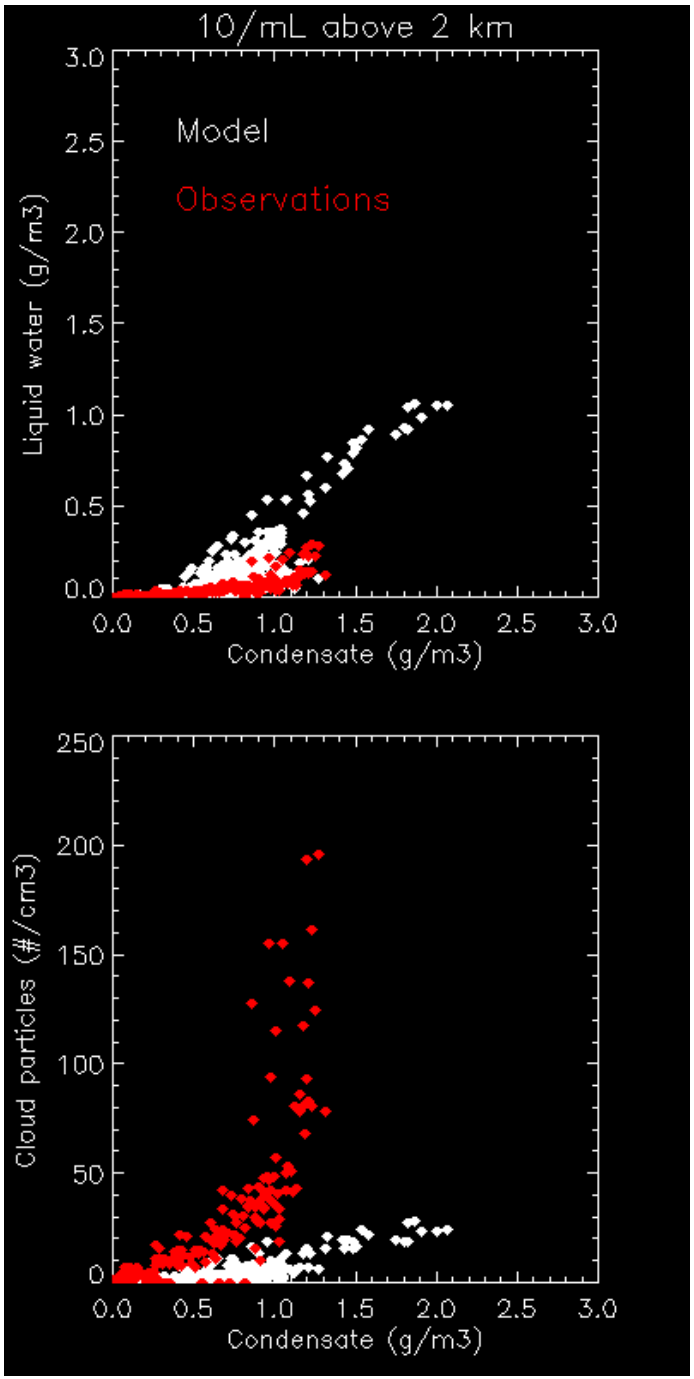
Boundary layer aerosol reduced to 400/mL



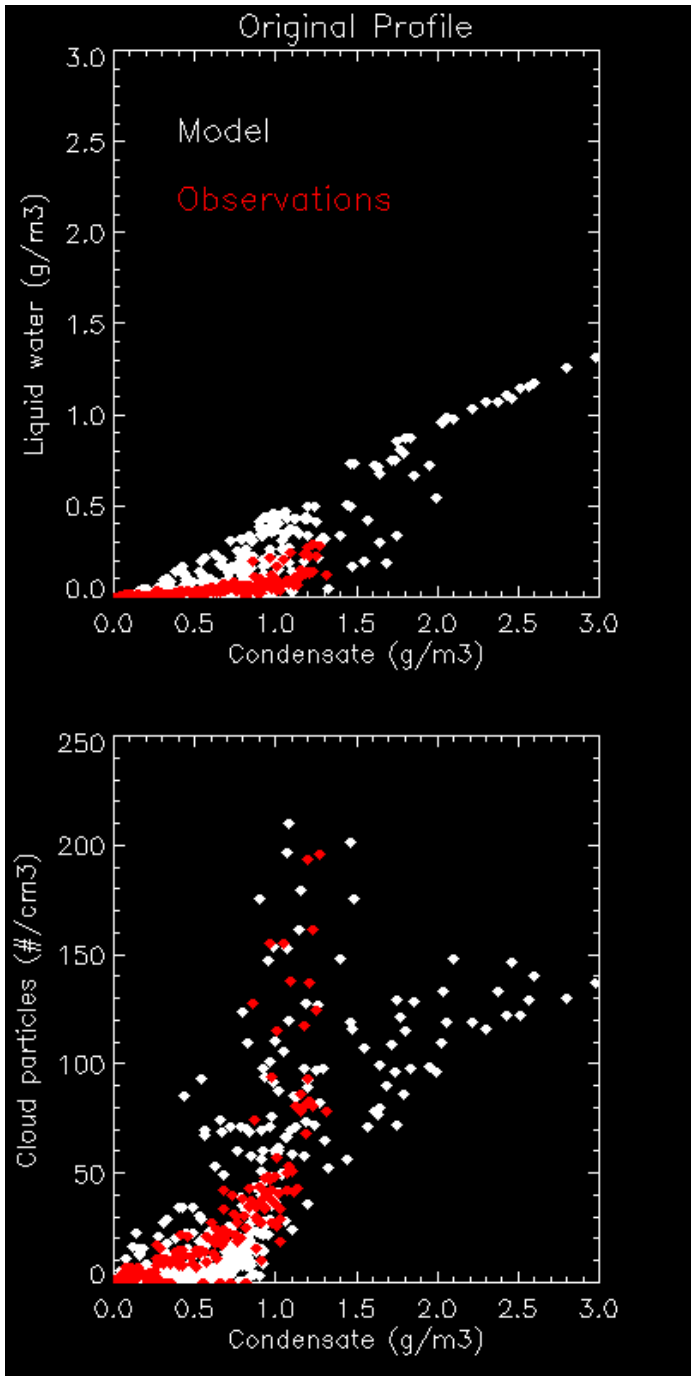


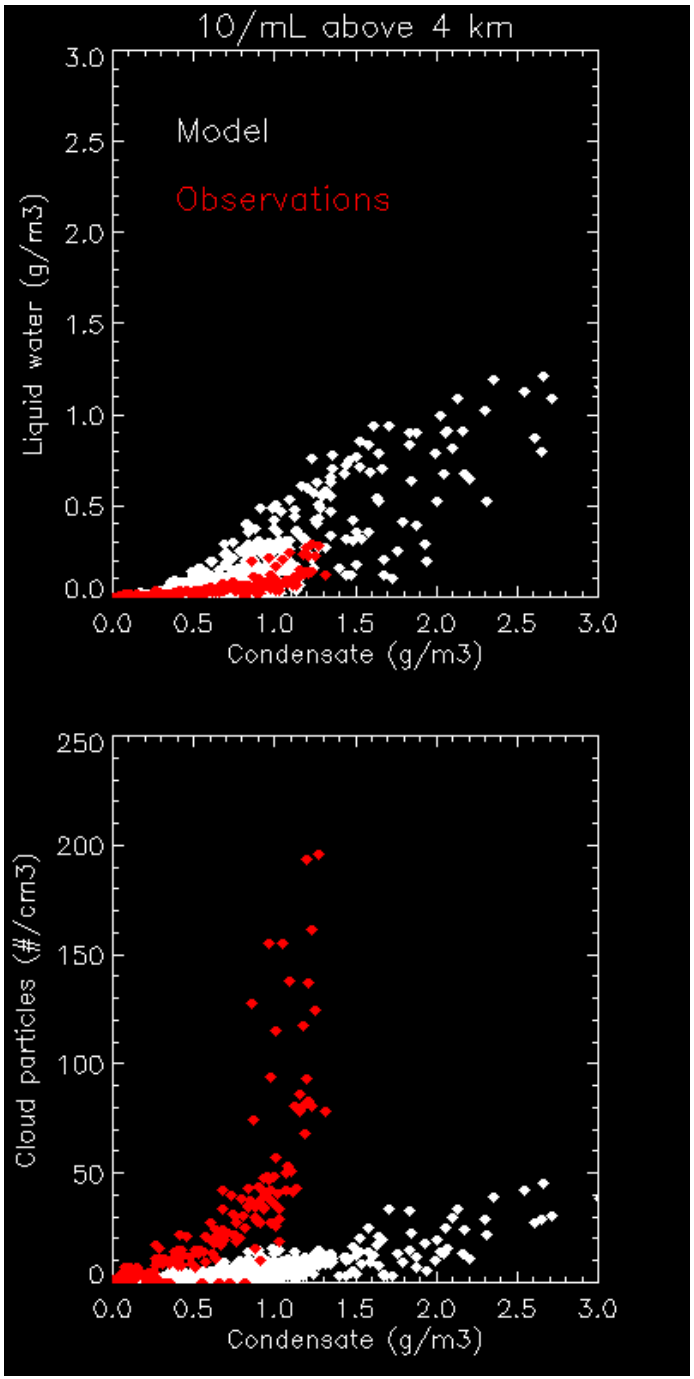
FT aerosol reduced to 10/mL above 2 km



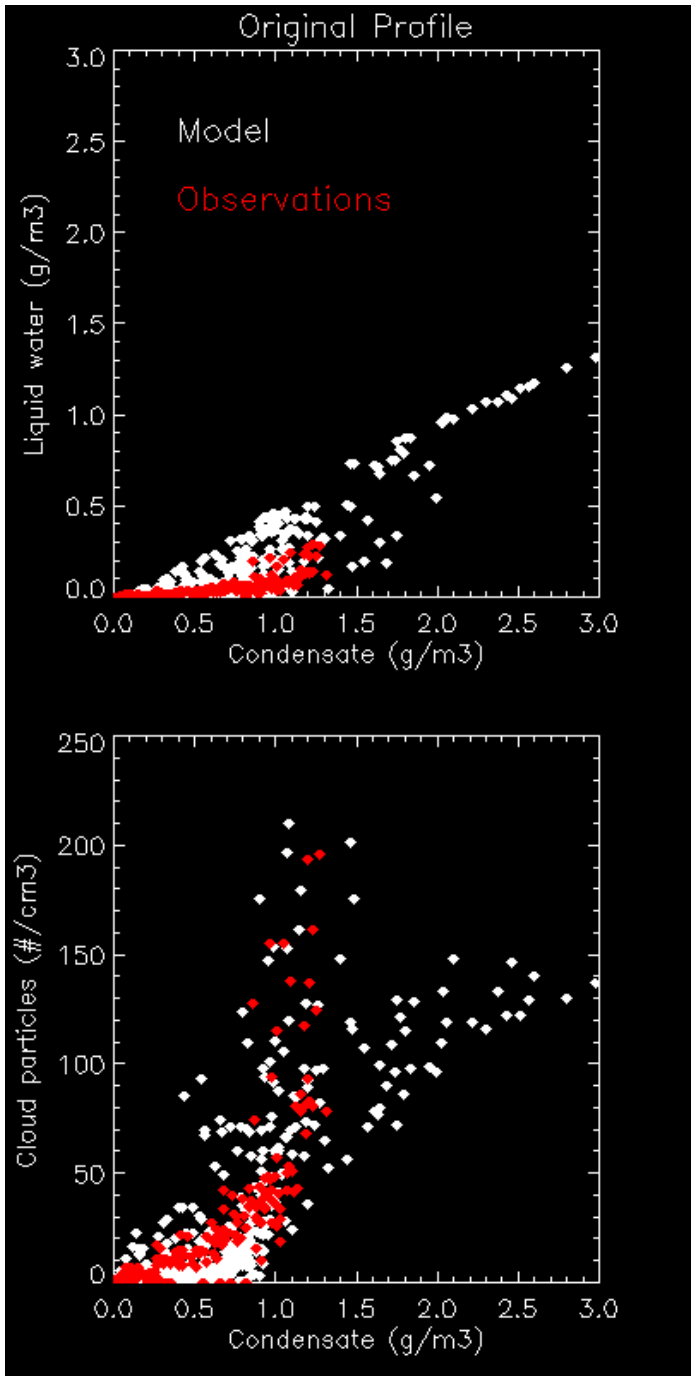


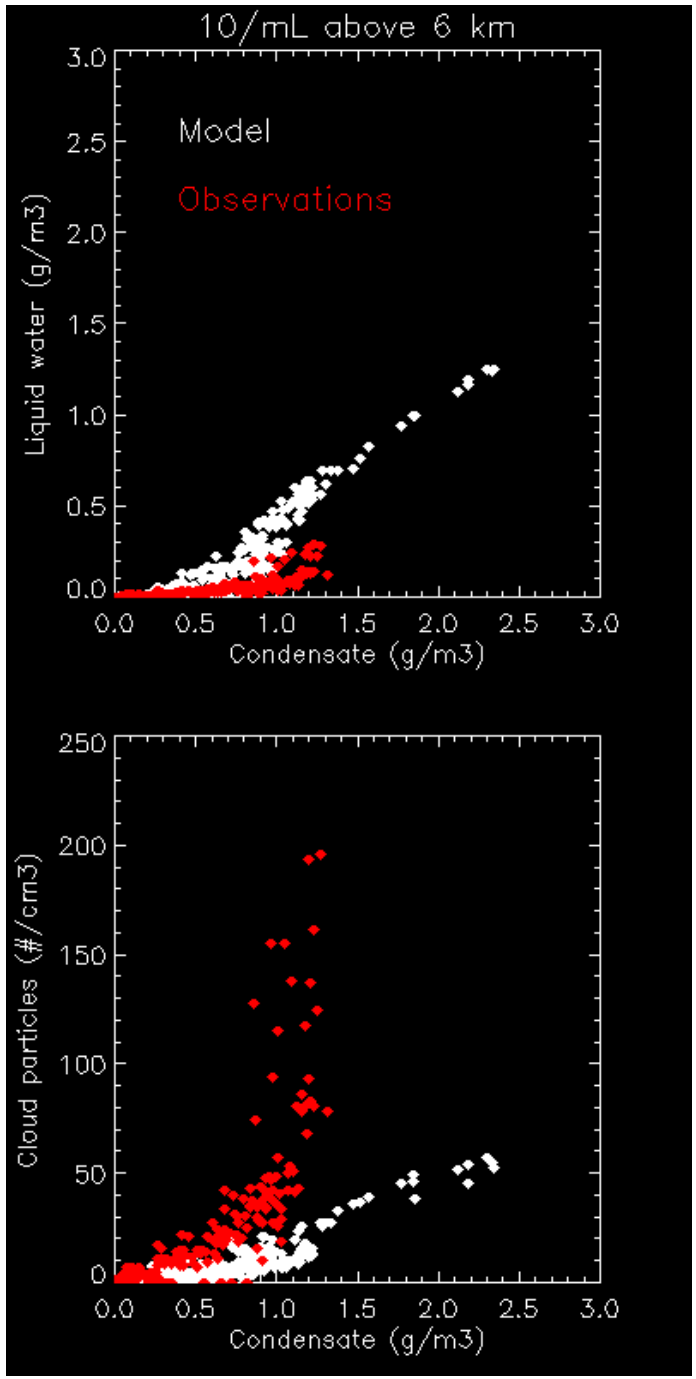
FT aerosol reduced to 10/mL above 4 km



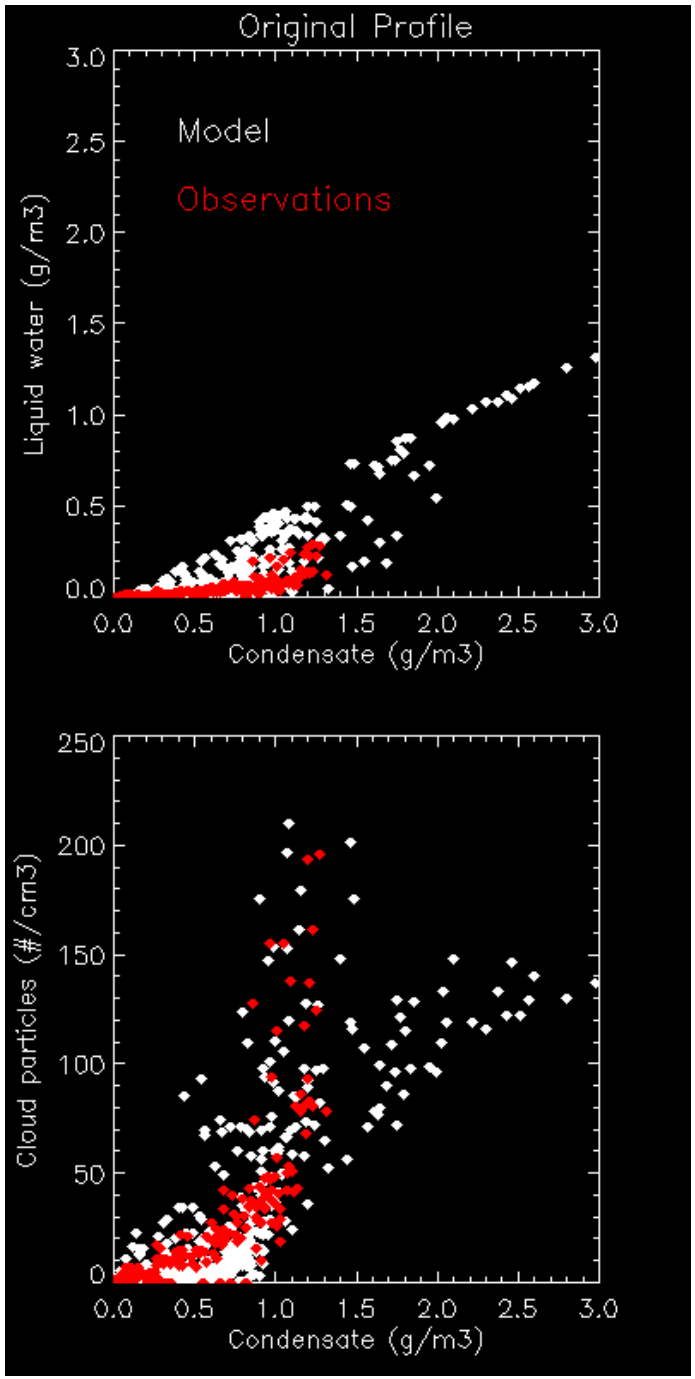


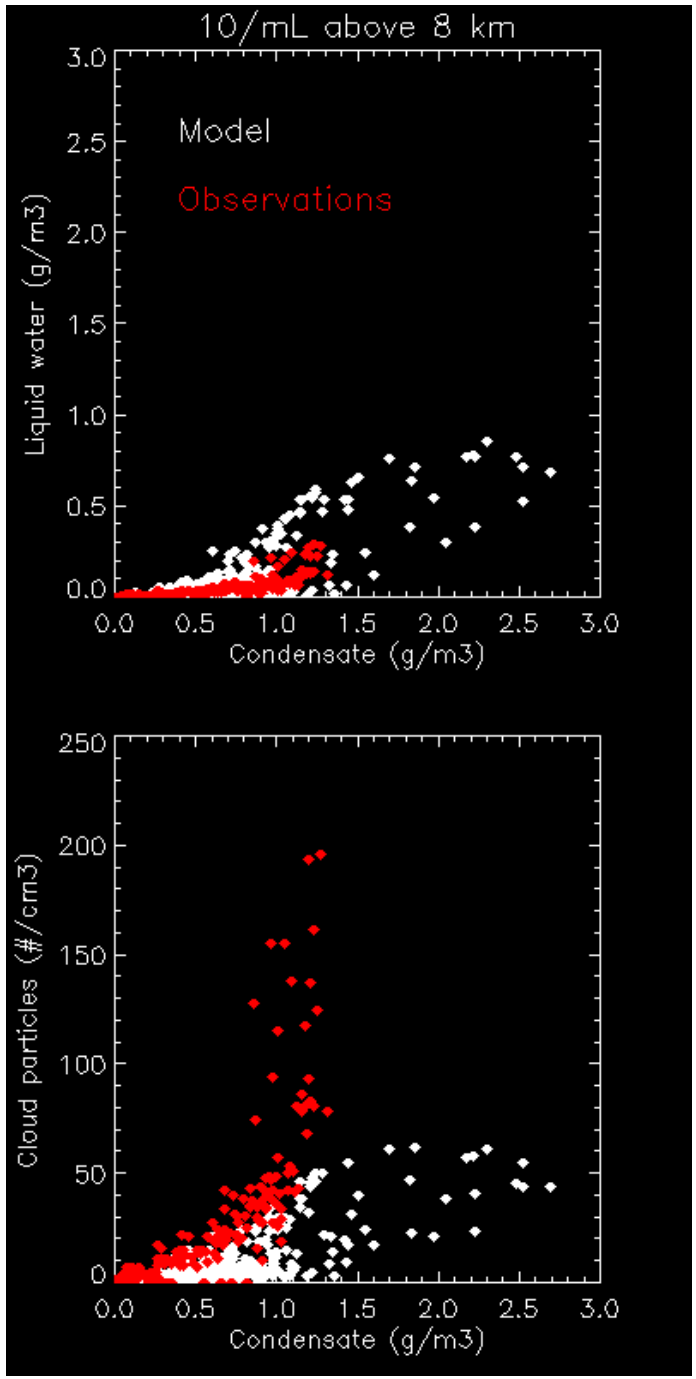
FT aerosol reduced to 10/mL above 6 km





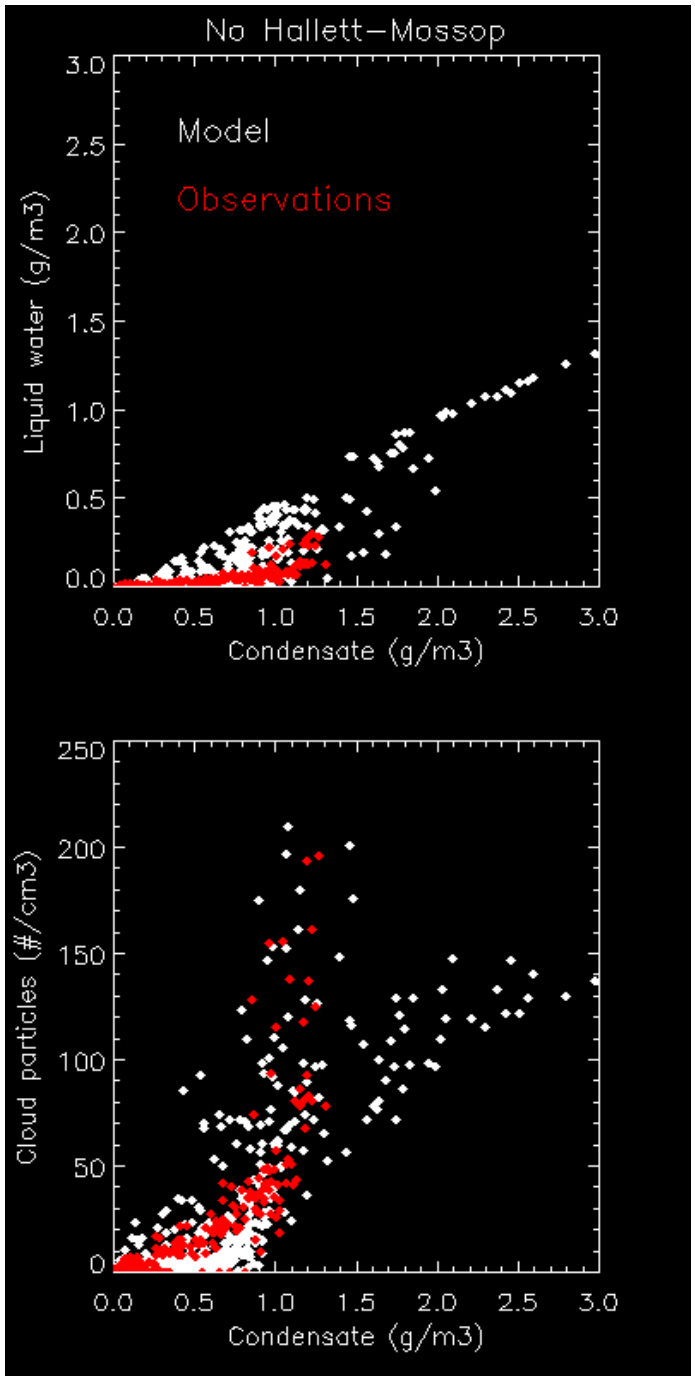
FT aerosol reduced to 10/mL above 8 km

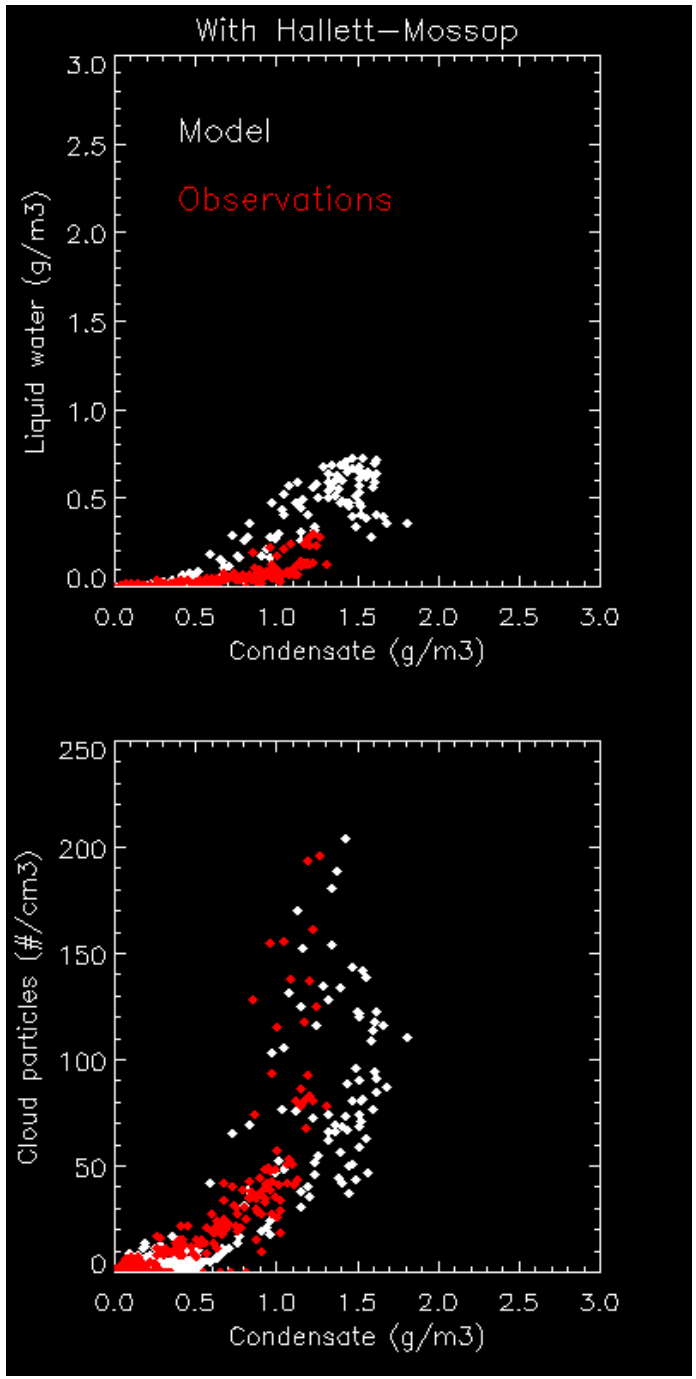




Is Hallett-Mossop ice crystal multiplication important?

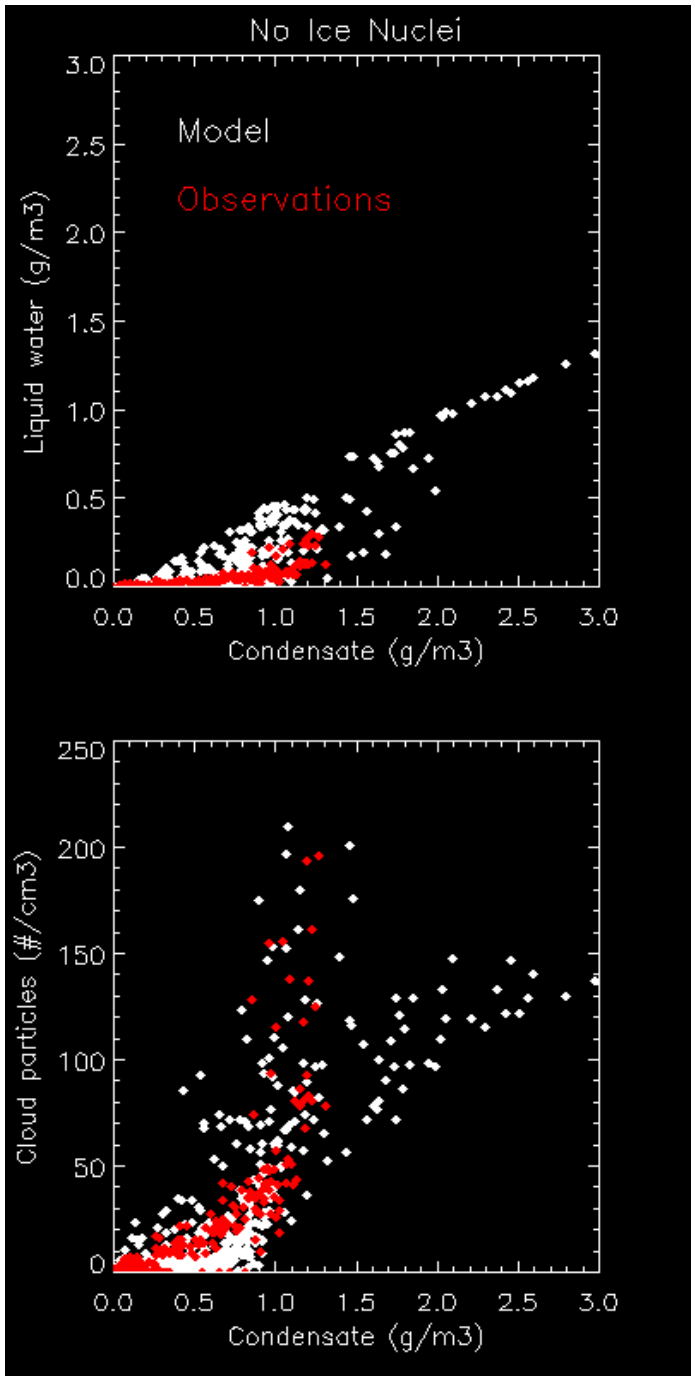
Hallett-Mossop ice crystal multiplication

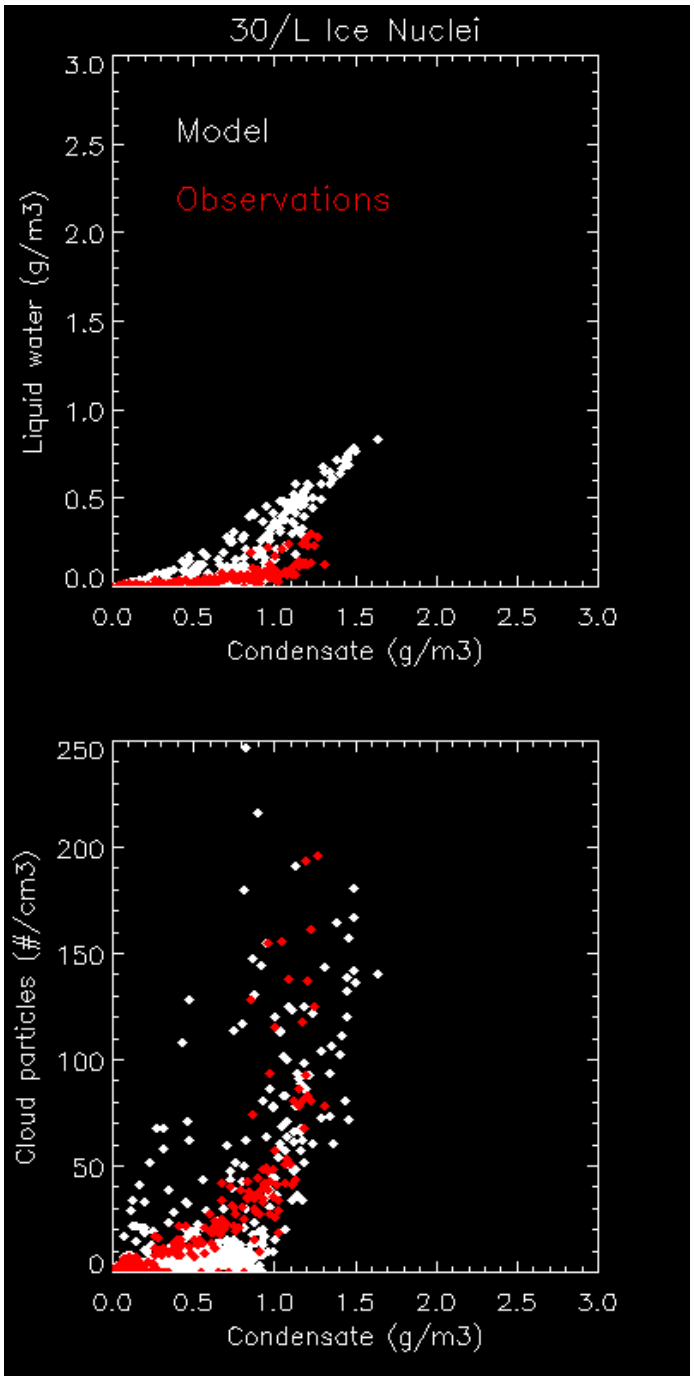




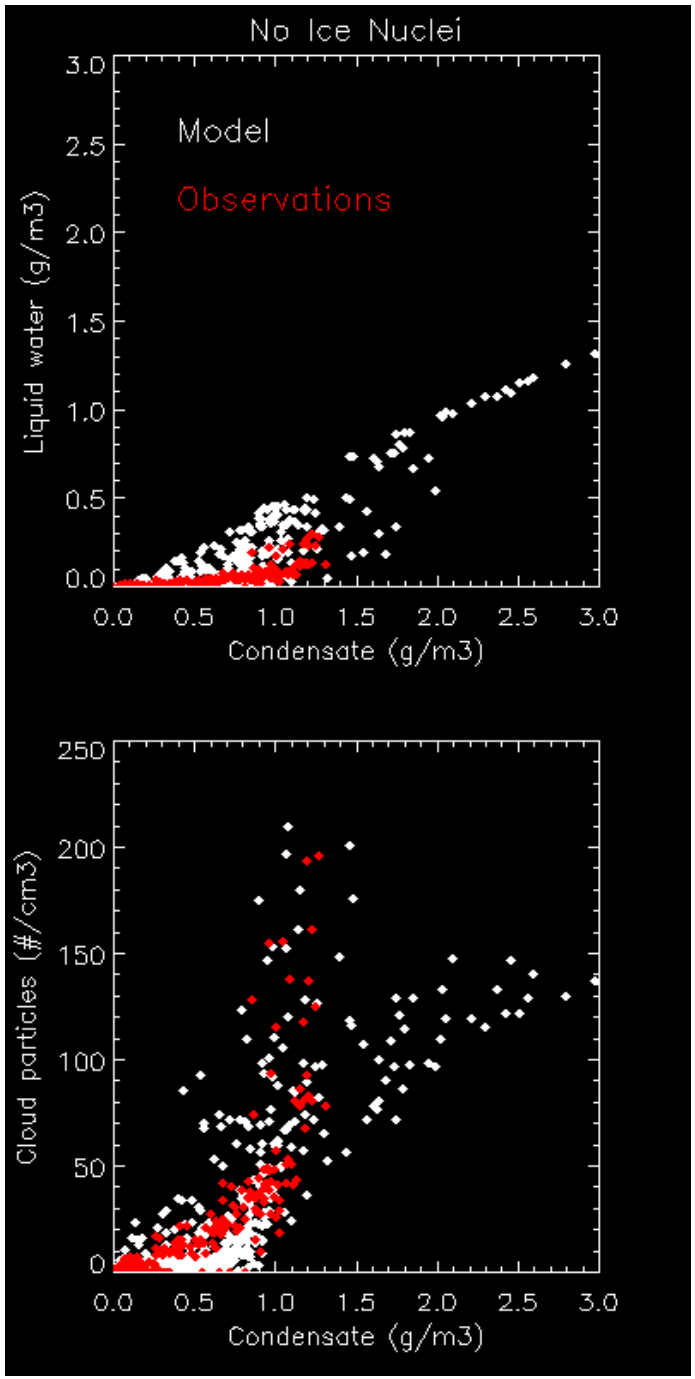
Is heterogeneous ice nucleation important?

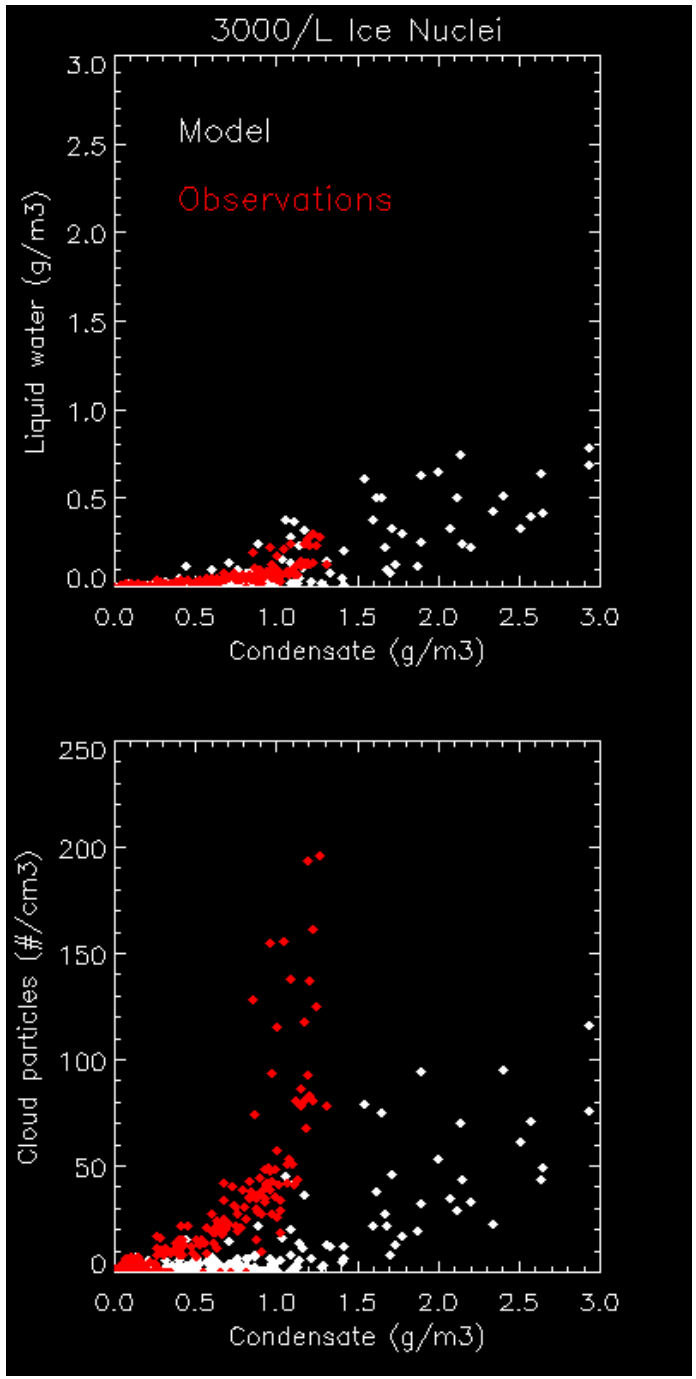
30/L ice nuclei active at -25C





3000/L ice nuclei active at -25C





Preliminary conclusions for July 18

- can homogeneous nucleation produce most ice crystals?
  - yes, it can
- are boundary layer or free tropospheric aerosols more important?
  - free tropospheric
- is Hallett-Mossop ice multiplication important?
  - yes, but not to number concentration
- is heterogeneous ice nucleation important?
  - yes, at high concentrations

Future Work

- improve aerosol representation
  - WB-57 CN size distributions
  - Citation ice nuclei
  - chemical composition
- compare predicted updraft core particle size distributions with observations
- compare predicted cloud base and cloud top properties with observations
- estimate measurement uncertainty
- estimate model uncertainty
  - time
  - space
  - bin resolution